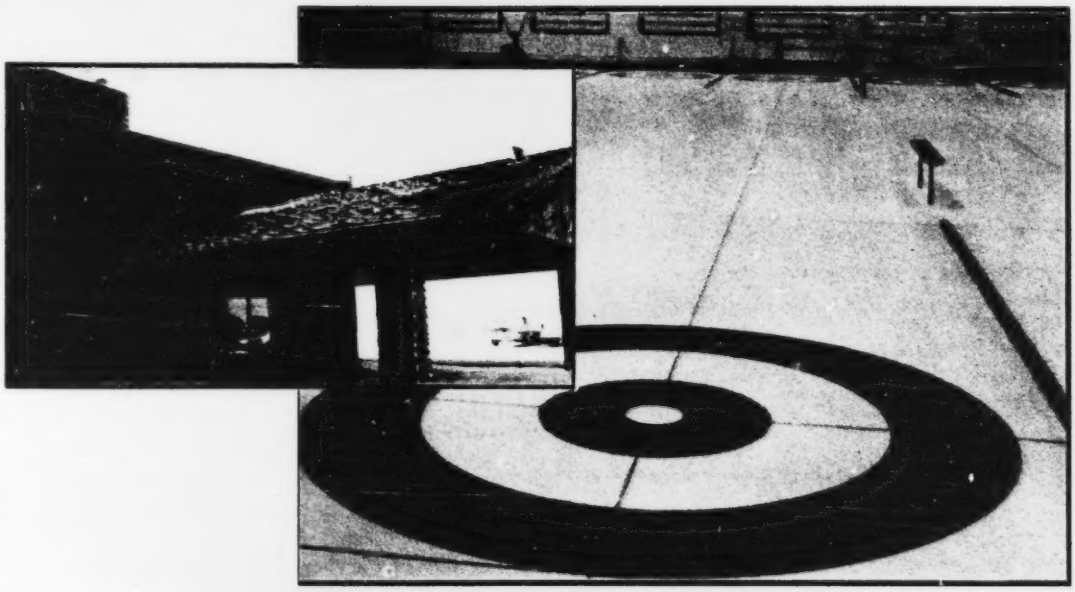
PREPARED BY:
UNIVERSITY OF MANITOBA
DEPARTMENT OF MECHANICAL ENGINEERING
AND
MANITOBA ENERGY AND MINES
CONSERVATION AND RENEWABLE ENERGY BRANCH



WESTWARD MALL PERFORMANCE ANALYSIS

PORTAGE LA PRAIRIE, MANITOBA

Manitoba
Energy and Mines

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1 EXECUTIVE SUMMARY

The Portage Curling Rink and Westward Village Inn complex was built for West Park Ltd. Mr. Larry Mauws, President, incorporated many energy conservation features into the complex. It was an existing demonstration of energy conservation from which an immense amount of knowledge could be learned by the evaluation of the special features. The objectives of the Conservation Renewable Energy Demonstration Agreement (CREDA) included the demonstration of energy conserving features of buildings and the commercialization of their application. Therefore, it was considered to be a valuable opportunity to conduct an energy balance and performance analysis on an existing demonstration facility. Manitoba and Canada provided CREDA funding for the Department of Mechanical Engineering, of the University of Manitoba to perform the study.

The complex, located in Portage La Prairie, Manitoba, included a curling rink, a motel, a shopping mall and a Canadian Tire store with an attached service garage. Heat was recovered from the ice-making plant and used to supplement the space heating of the complex during the winter season. Summer cooling was achieved by the use of ground water at an average temperature of 12°C (54°F), which was obtained from sandpoints placed immediately under the complex. Four large concrete storage tanks (225,000L each) were incorporated into the basement of the complex. Two of the tanks were used to store cold water and the other two were for hot water storage.

The DOE-2 computer program, produced by the U. S., Department of Energy, was used for modelling of building energy consumption and the evaluation of the effect of the special features on the energy utilization. The program performs an hourly simulation and analyzes the dynamic characteristics of buildings. In addition to weather data, the program input requires the architectural features, mechanical equipment performance data and the activity levels within the complex.

The major features that were modeled were the heat recovery and cooling systems. The condenser cooling water of the ice-making plant is discharged to storage at 43°C (110°F) and then reused to supplement the heating load of the complex. In this case the space heating load is relatively large and since the load coincided with the main function of the complex, curling, little storage is needed. The use of the swimming pool for storage of the waste heat was investigated. For this complex, it proved to be adequate with a 3°C (5°F) temperature variation but the importance of temperature control on a swimming pool was emphasized. The cold water storage forms an integral part of the summer cooling system since the existing three

sandpoints are of insufficient capacity to meet the higher cooling load demands. The cooling water is pumped and stored during the night and early morning to meet the daily cooling peaks. The computer model was used to study other energy conserving features including a solar air preheating system, the replacement of natural gas by electrical heating for space and hot water heating and waste heat recovery from exhaust air.

The results of the analysis indicated that the existing complex had an energy consumption index of 1,046 $MJ/m^2/yr$ (27.0 $kW \cdot h/ft^2/yr$), while the estimated requirements of a complex of conventional design and equal size were 1,330 $MJ/m^2/yr$ (34.3 $kW \cdot h/ ft^2/yr$). The recovered energy from the ice-making plant provided 45.6% of the space heating requirments of the complex. The corresponding saving was 553 MW·h/yr or $12,000/yr. The use of ground water provided almost free cooling for the complex and the savings were approximately 212 MW·h/yr which was equivalent to $2,620/yr.

Heat recovery systems for ventilation exhausts were evaluated, the saving was 146.7 MW·h/yr or $3,800/yr. with an initial cost estimated to be $22,000.

A solar system for air preheating with 185 m^2 (2000 ft^2) of panel was simulated by the computer model which integrated it with the existing air handling system. The computer model indicated that the equivalent 47.9 MW·h/yr was collected and thus saved $1,240/yr. The initial cost of such a solar system was estimated to be between $20,000 and $30,000.

The replacement of the natural gas heating plant by an electric boiler was simulated and resulted in an energy saving of 196 MW·h/yr but at an increase cost of $2,800/yr.

The conclusions and recommendations point out the benefits of using waste heat recovery from the ice-making plant and of the use of ground water for cooling. However, many of the benefits accrued for this curling rink, motel, shopping mall complex are site specific and careful engineering analyses should be performed in other cases to avoid costly mistakes. For instance, the storage for waste heat hot water was oversized but because of the marginal cost of the storage and comprehensive savings the financial penalties were insignificant. The use of ground water for cooling the complex, requires an optimization of the components of the system which involves analyses of the size and depth of the ground water sources, the capacity of the pumping system, the size of the storage and the magnitude of the cooling load. The need for adequate engineering analyses is therefore emphasized.

1. RÉSUMÉ ADMINISTRATIF

Le complexe du stade de curling de Portage et du Westward Village Inn a été construit pour West Park Ltd. Le président de cette compagnie, Monsieur Larry Mauws, a fait incorporer dans le complexe plusieurs techniques de conservation de l'énergie. Il s'agissait d'une démonstration concrète de conservation de l'énergie grâce à laquelle de précieux renseignements pourraient être obtenus par suite de l'évaluation des techniques spéciales utilisées. Les objectifs du programme de démonstration des énergies renouvelables et des économies d'énergie (CREDA) comprennent la démonstration des techniques de conservation de l'énergie dans les édifices et leur commercialisation. L'occasion semblait donc merveilleuse de procéder à une analyse d'équilibre et de rendement énergétique sur une installation existante utilisée aux fins de démonstration. Le Manitoba et le Canada ont fourni des fonds, dans le cadre du programme CREDA, au département de Génie mécanique de l'université du Manitoba pour effectuer l'étude.

Le complexe, situé à Portage-la-Prairie, comprend un stade de curling, un motel, un centre commercial et un magasin Canadian Tire pourvu d'un atelier de réparation d'automobiles. La chaleur récupérée de l'installation frigorifique a constitué une source de chauffage d'appoint pour le complexe durant les mois d'hiver. Pour assurer le refroidissement du complexe pendant l'été, on a utilisé de l'eau souterraine à une température moyenne de 12°C (54°F) obtenue au moyen de pointes de puits enfoncées directement sous le complexe. Quatre énormes réservoirs en béton pouvant contenir 225 000 litres chacun ont été construits dans le sous-sol du complexe. Deux de ces réservoirs ont été utilisés pour l'emmagasinement de l'eau froide et les deux autres pour l'eau chaude.

On a eu recours au programme informatique DOE-2 mis au point par le ministère de l'énergie des États-Unis pour la modélisation de la consommation d'énergie de l'édifice et l'évaluation de l'effet des techniques spéciales sur les besoins en énergie. Le programme effectue une simulation toutes les heures et il analyse les caractéristiques dynamiques des édifices. Outre les données météorologiques, le programme doit tenir compte des caractéristiques architecturales, des données sur le rendement des dispositifs mécaniques et des niveaux d'activité dans le complexe.

Les techniques que le modèle informatisé tentait surtout de simuler étaient les systèmes de refroidissement et de récupération de la chaleur. L'eau servant à refroidir le condensateur de la machine frigorifique était déversée dans le réservoir d'emmagasinement à 43°C (110°F) et était utilisée ensuite comme source de chauffage d'appoint pour tout le complexe. Dans le cas à l'étude, les besoins en chauffage étaient relativement élevés et puisqu'il s'agissait essentiellement de chauffer l'élément principal du complexe, c'est-à-dire le stade de curling, très peu d'eau était emmagasinée. On a également étudié la possibilité d'emmagasiner la chaleur résiduelle dans l'eau de la piscine. Pour le complexe en question, cette méthode s'est avérée satisfaisante et a produit des variations de température ne dépassant pas 3°C (5°F), mais une telle expérience a fait ressortir l'importance du contrôle de la température pour une piscine. L'emmagasinement de l'eau froide est une partie intégrante du système de refroidissement pendant les mois d'été puisque les trois pointes de puits n'ont pas un débit suffisant pour répondre à une demande de refroidissement plus élevée. L'eau de refroidissement est emmagasinée dans les réservoirs pendant la nuit et le début de la matinée et utilisée ensuite pendant la période de la journée où la demande de refroidissement est maximale. Le modèle informatisé a permis d'étudier

d'autres méthodes de conservation de l'énergie comme le système de réchauffage préalable de l'air à l'énergie solaire, le remplacement du gaz naturel par l'électricité comme source de chauffage de l'air et de l'eau, et la récupération de la chaleur résiduelle dans l'air d'évacuation.

Les résultats de l'analyse ont révélé que le complexe existant avait un indice de consommation d'énergie de 1 046 $MJ/m^2/a$ (27,0 $kW-h/pi^2/a$), tandis que l'indice calculé d'un complexe de conception conventionnelle et de dimensions égales serait de 1 330 $MJ/m^2/a$ (34,3 $kW-h/pi^2/a$). L'énergie récupérée de l'installation frigorifique a comblé 45,6% des besoins en chauffage du complexe. L'énergie économisée correspondait à 553 $MW/m^2/a$, soit 12 000 $/a. L'utilisation de l'eau souterraine a permis d'assurer à peu de frais le refroidissement du complexe et les économies ainsi réalisées ont été d'environ 212 MW-h/a, ce qui équivaut à 2 620 $/a.

L'évaluation des systèmes de récupération de la chaleur des conduits d'évacuation de l'air a révélé des économies de 146 MW-h/a, soit 3 800 $/a, les frais d'installation initiaux se chiffrant à environ 22 000 $.

Le modèle informatisé intégrait au système de chauffage et de circulation d'air existant une installation simulée d'énergie solaire pour le réchauffage préalable de l'air comprenant 185 m^2 (2 000 pi^2) de panneaux. D'après le modèle informatisé, une quantité d'énergie équivalant à 47,9 MW-h/a été recueillie, pour une économie annuelle de 1 240 $. Les frais initiaux estimatifs du système d'énergie solaire se situent entre 20 000 et 30 000 dollars.

Le remplacement simulé d'une installation de chauffage au gaz naturel par une chaudière à l'électricité à résulté en une économie d'énergie de 196 MW-h/a, mais les frais ont alors augmenté de 2 800 $/a.

Les conclusions et les recommandations formulées soulignent les avantages découlant de la récupération de la chaleur produite par l'installation frigorique et de l'utilisation de l'eau souterraine comme agent de refroidissement. Il faut noter, toutefois, que plusieurs des avantages obtenus dans le cas de ce complexe particulier comprenant un stade de curling, un motel et un centre commercial, sont propres et exclusifs à cet emplacement et que pour tout autre endroit, des études techniques complètes devraient être effectuées afin d'éviter des erreurs coûteuses. Notons, par exemple, les réservoirs d'emmagasinement de l'eau réchauffée par la chaleur perdue auxquels on a donné des dimensions plus grandes qu'il n'était requis, du fait que leurs coûts de construction étaient peu élevés et que des économies substantielles pouvaient être réalisées. L'utilisation de l'eau souterraine pour le refroidissement du complexe exige l'optimisation des divers éléments du système, c'est-à-dire la détermination de la capacité et de la profondeur des nappes d'eau souterraines, du débit des pompes, des dimensions des réservoirs d'emmagasinement et des besoins de refroidissement. Cette expérience a donc fait ressortir l'importance de faire procéder à des études techniques détaillées.

2 INTRODUCTION

2.1 General

The many energy conserving features incorporated into the design and construction of the Portage Curling Rink and Westward Village Inn complex were the innovations of Mr. Larry Mauws, President, West Park Ltd. Information for the design and construction was garnered by attending conferences, by reading and by consulting builders and designers. The complex consists of a curling rink, a full service motel with an indoor swimming pool, a shopping mall and a Canadian Tire Store with a service garage. This work served to initiate energy saving systems in other rinks and ice-making plants in Manitoba; in particular the waste heat recovery system incorporated by the Elm Creek Curling Club, and the use of waste heat for subfloor heating, to prevent ground heavage under the Westco Storage Ltd., Portage la Prairie cold storage plant.

The main energy conserving systems are, waste heat recovery from the ice-making plant to supplement the space heating and the use of ground water for summer cooling. Features added since this study was initiated include the use of ground water at 12°C (54°F) for preheating air supplies to the curling rink and the motel, and the reclamation of heat from the exhaust air of the banquet room during periods of intensive use.

The complex was considered to be an existing energy conserving demonstration and the study was thus funded by the Manitoba/Canada Conservation and Renewable Energy Demonstration Agreement (CREDA) and performed by the Department of Mechanical Engineering, the University of Manitoba.

2.2 Objective and Scope

The objective of this study was to evaluate the energy saving systems in the Portage Curling Rink and Westward Village Inn complex.

The heat normally rejected by the condenser of the ice-making plant is used to supplement the heating plant. The first step was then to evaluate the amount of heat recovered from ice making. The second step was to evaluate the energy saved by the use of the ground water for summer cooling. The study was structured in two distinct phases. The first phase covered the evaluation of existing systems of the complex and their operation. The second phase concentrated on identifying the potential and further improvements in energy conservation features that could be introduced into the facilities.

3 DESCRIPTION OF FACILITIES AND PROJECT PLAN

3.1 Existing Architectural Design

The complex consists of two stories, a partial basement and a total floor area of 14,300 m^2 (154,500 ft^2). It is basically composed of a curling rink, a motel, a central shopping mall and a Canadian Tire store. Figs. 1 to 3 illustrate the configuration of the facility.

The curling rink, with a total area of 2,320 m^2 (24,970 ft^2), includes eight sheets of curling ice, with a spectator area on the ground floor and a lounge on the second floor. The building shell is comprised of aluminum paneling and insulated decking. The thermal resistance value of the wall is RSI 4.4 (R25) and for the roof is RSI 3.5 (R20). The concrete floor is 300 mm (12") thick without insulation.

The Westward Village Inn, with 2,280 m^2 (24,500 ft^2) of floor area, consists of 60 rooms, lounges, a lobby, a dining room, a coffee shop, a kitchen, a banquet room and an indoor 6mx9m (20ftx30ft) swimming pool. The motel windows are triple glazed with an exterior canopy and interior drapes. The exterior walls are made of 100 mm (4") face brick on the ground floor and 50 mm (2") of cedar wood on the second floor; all exterior walls contain 125 mm (5") of batt insulation and are wood finished on the inside. The overall thermal resistance for the wall was determined to be RSI 3.5 (R20). Roofing is built-up roofing with 175 mm (7") of rigid insulation having a thermal resistance value of RSI 5.9 (R33). The ground floor is 300 mm (12") thick concrete. The basement of the motel contains a mechanical room, a laundry room, a maintenance workshop and four water storage tanks of 225,000 L (50,000 gal) each. All of the basement walls and floors are concrete, without insulation.

Both the central shopping mall and the Canadian Tire store are of a similar structure. All windows are double glazed. The exterior walls facing north are of the same structure as the motel exterior wall. Other exterior walls are of panel structure similar to the rink. Thermal resistance value of the exterior wall is about RSI 2.5 (R14) and the roof is RSI 3.5 (R20). There is no basement in this section of the complex.

Generally, the entire complex is in good condition, well insulated, sealed and without any visible cracks.

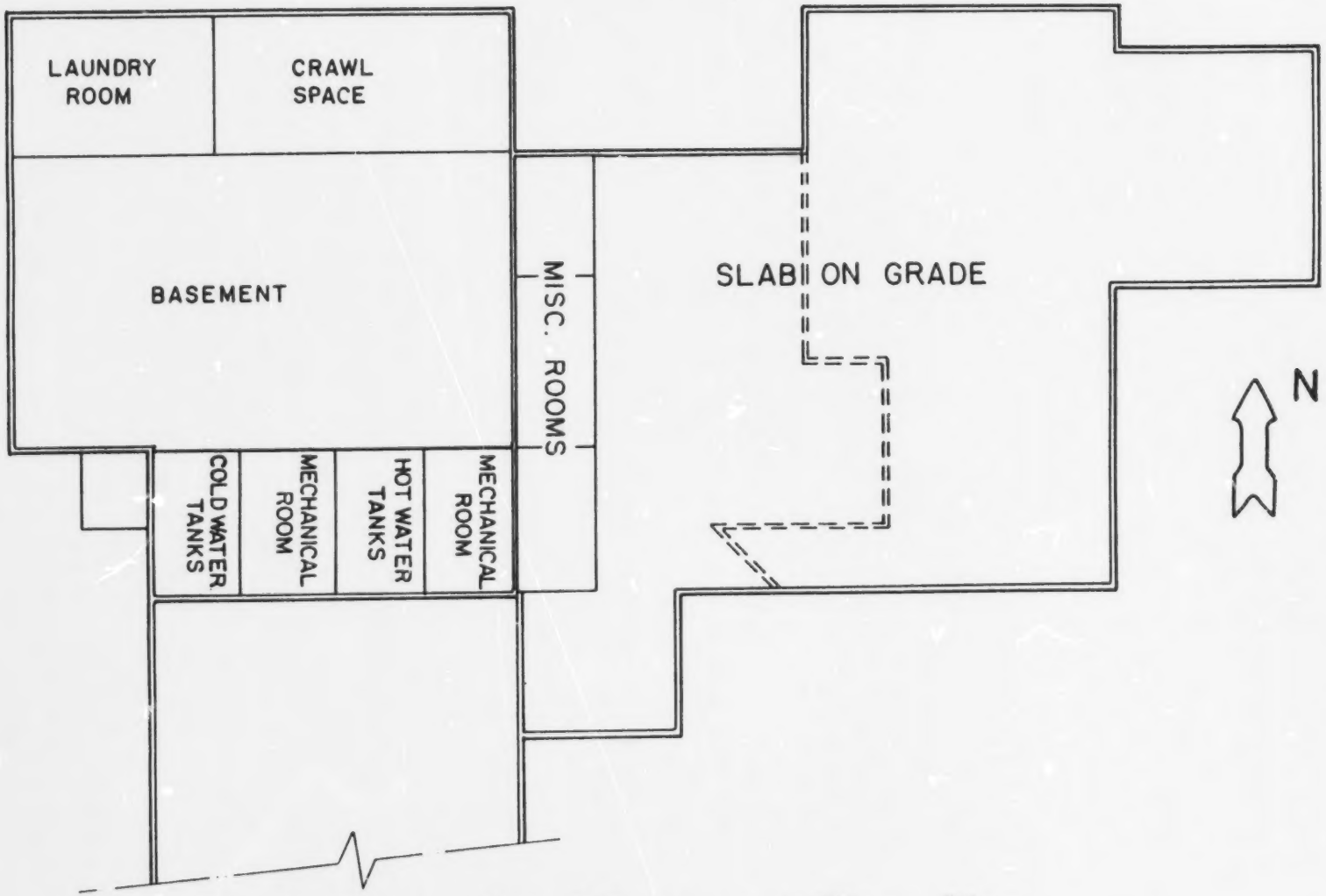


Fig. 1 Schematic of Basement Floor Plan
Portage Rink and Westward Inn Complex

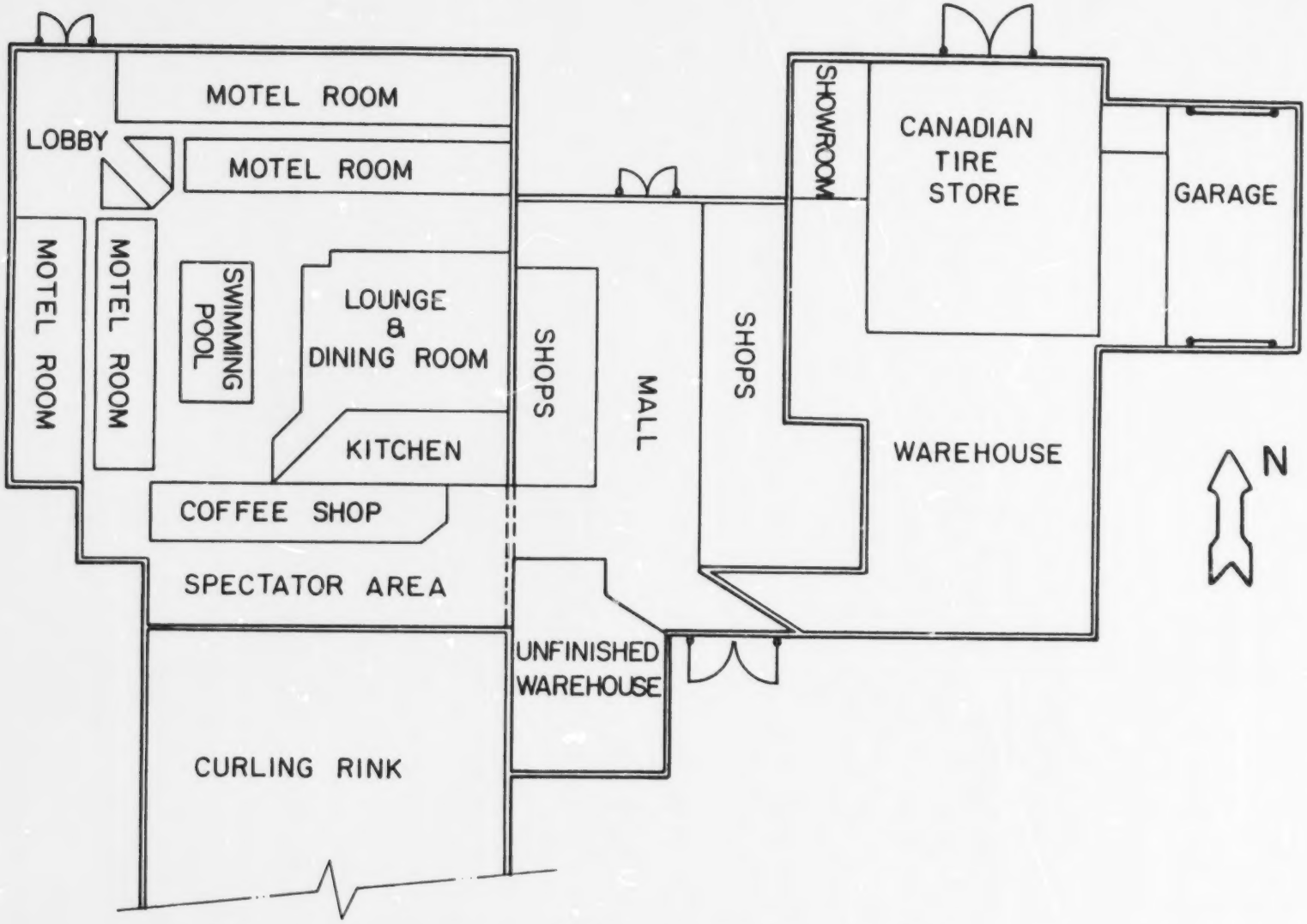


Fig. 2 Schematic of the Ground Floor Plan
Portage Rink and Westward Inn Complex

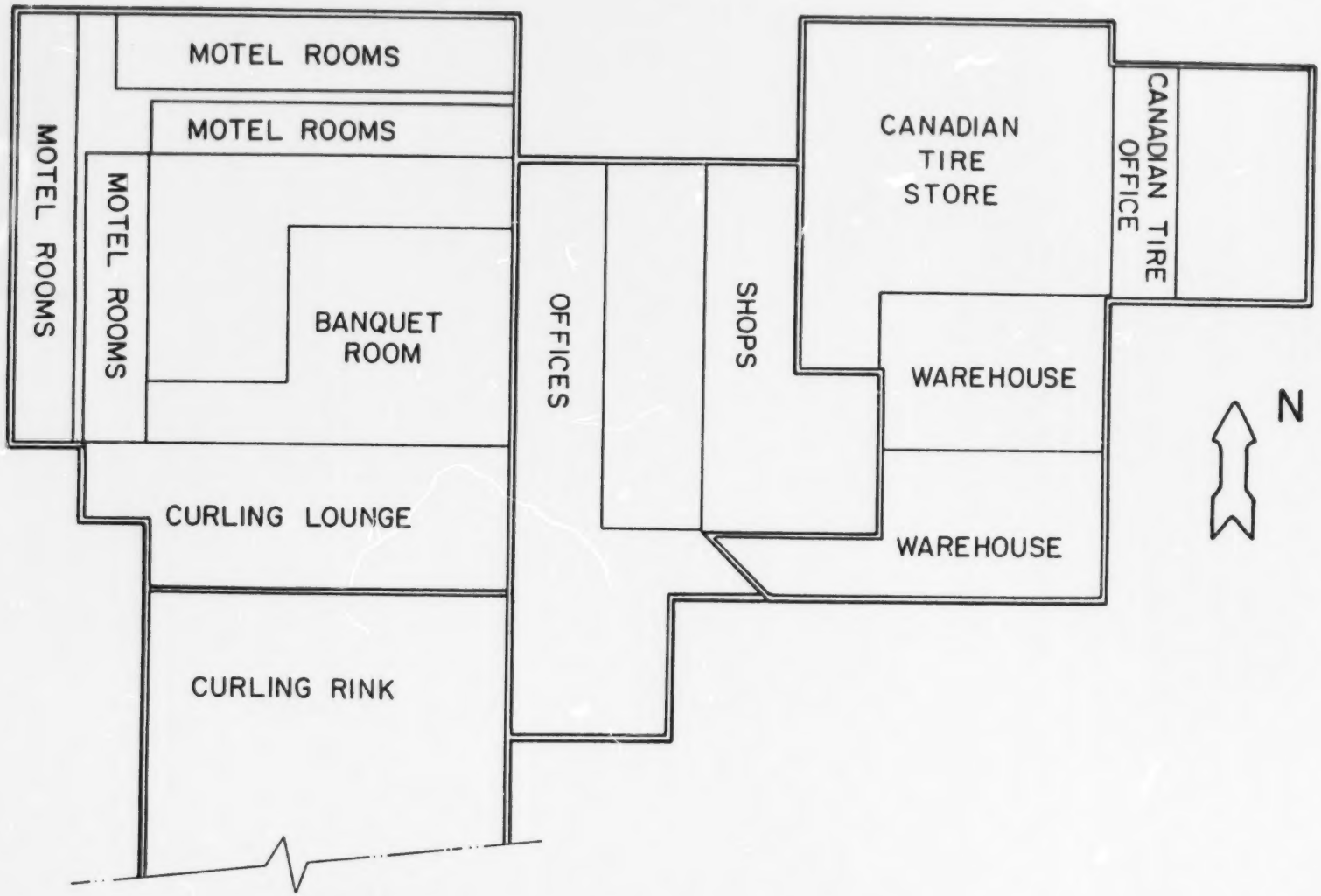


Fig. 3 Schematic of 2nd Floor Plan
Portage Rink and Westward Inn Complex

3.2 Existing Mechanical Systems

There is a total of ten air handling units (AHU) for the complex. Their operational characteristics are shown in Table 1. Fig. 4 shows an air flow schematic of the complex.

The motel section has seven AHU for ventilation. The system is supplemented with a four - pipe fan coil system which is installed along the perimeter of the motel. A heat recovery coil is installed for motel room ventilation. (Refer to AHU 4 & 5 in Table 1). During the summer AHU 2 operates with 100% fresh air, while during the winter operation it transfers air from the curling rink for ventilation. AHU No. 3 is equipped with a cooling coil. This unit dehumidifies air from the swimming pool area and transfers it to the lounge and dining room. It is eventually exhausted through the kitchen ventilating system.

The curling rink unit, AHU No. 1, operates in the winter season, and occasionally in summer when there are activities in the rink. The hot water heating and ground water cooling are supplied to the unit by the central plant; a standby chiller is available for the larger summer cooling loads in the rink.

The shops in the central shopping mall are equipped with 20 compartmental four-pipe fan coil units installed in the ceiling space. Their capacities range from 280 L/s (600 cfm) to 450 L/s (960 cfm). The central plant supplies hot water for heating and ground water for cooling. The units operate with 100% return air. The air supplied to the curling spectator area is transferred via the mall to the shops mainly due to pressure difference. A small air conditioning unit is installed for backup in the largest shop in the Mall.

The Canadian Tire store has two central air handling units with a capacity of 2,220 L/s (4700 cfm) and 820 L/s (1740 cfm) respectively. A gas fired unit heater is installed in the warehouse at the back of the shopping area. Another air conditioning unit is installed in the office to provide suitable conditions for the computer system. The Canadian Tire garage has two gas fired unit heaters at 58 kW (200,000 Btu/h) input capacity. The units are equipped with timers for control.

The central plant supplies most of the heating and cooling required by the complex; the gas fired unit heaters and the two air conditioning units supply the rest. Approximately 46% of the heating load required by the complex is recovered from the ice-making plant.

Heat recovered from the condenser is transferred to storage and distributed for heating purposes. A gas fired hot water boiler is installed for boosting purposes. The boiler has two stages of heating capacity -- a higher input of 477 kW (1,630,000 Btu/h) and a lower input at 96 kW (326,000 Btu/h). The seasonal efficiency of the boiler was found to be 59%. There is no central refrigeration plant in the complex. Approximately 4.0 L/s (60 gpm) of ground water at an average temperature of 12.2°C (54°F) were supplied by three sand point stations for cooling. Refer to Fig. 5 for system schematic.

The central ice-making plant of the curling rink includes three 26 kW (35 hp) compressors, each capable of producing 63 kW (18 tons) of cooling. The evaporator operates at 12.2°C (10°F) and 283 kPa (41 psi) gauge pressure. The condenser operates at 43.3°C (110°F) and 1,490 kPa (216 psi) gauge pressure. This corresponds to a compression ratio of 4.0. The performance characteristics of the ice-making plant are provided in Appendix B. The brine temperature was recorded to be at -8.6°C (16°F) supplying the rink and returning at -6.7°C (20°F). The compression system does not have an unloading device. Thus all compressors were on a three-step thermostatic switch.

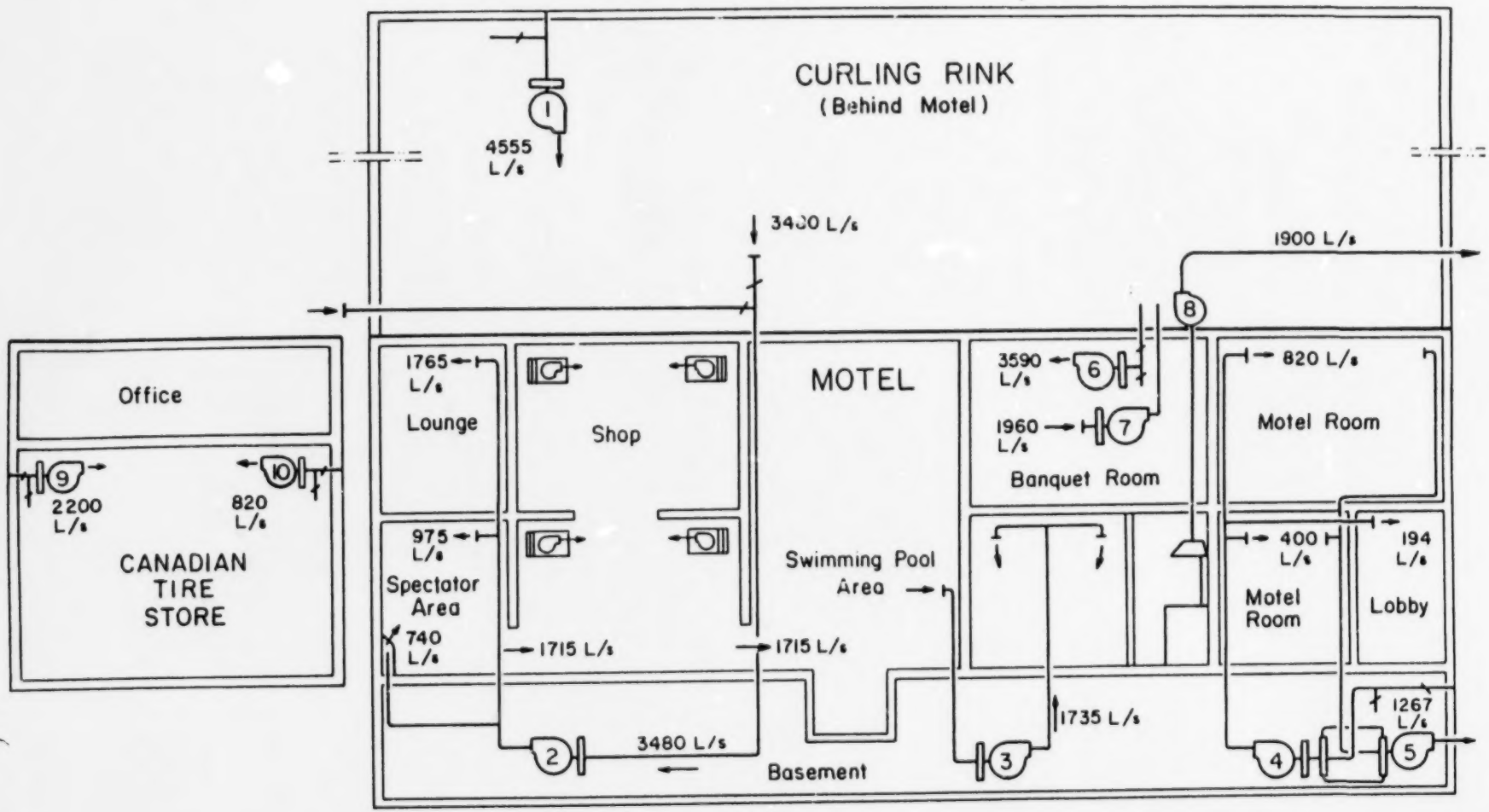
Two hot water storage tanks and two ground water storage tanks of 225,000 L (50,000 gal) each, are used to store the heat recovered from the ice-making plant and the ground water from the sand point stations. The stored hot/cold water is distributed to other HVAC systems. The overflow from the tanks is directed outside through the weeping tiles and returned back to underground.

Water temperature in the swimming pool is maintained at approximately 28°C (82°F). No pool water heater is used. Instead a shell and tube type heat exchanger is used. Swimming pool water runs inside the tube and the system hot water runs on the shell side. It was estimated that approximately 0.23 kg/min (30 lb/hr) of moisture evaporated from the pool surface, resulting in a 9 kW dehumification load. The use of swimming pool water for heat storage is discussed in section 5.2.

Two gas fired hot water heaters of 107 kW (365,000 Btu/h) capacity each provide the domestic hot water. Laundry facilities include two washers and two dryers of 30 kW (105,000 Btu/hr) which were operated during the day shift.

AHU NO.	DESCRIPTION	AIR SUPPLY		FLOW DELIVERED L/s (cfm)	EQUIPPED WITH HEAT RECOVERY COIL
		From	to		
1	Curling Rink unit	outside	curling rink	4555 (9650)	No
2	Basement mechanical room	curling rink	curling lounge	1765 (3740)	No
		curling rink	curling spectator	975 (2065)	No
		curling rink	curling wall unit	740 (1570)	No
3	Basement dehumidifying	swimming pool	lounge & dining	1735 (3675)	No
4	Motel room supply	outside	motel room	1400 (2960)	Yes
5	Motel room exhaust	motel room	outside	1267 (2685)	Yes
6	Banquet room supply unit	outside	banquet room	3590 (7610)	No
7	General exhaust	general exhaust	outside	1960 (4150)	No
8	Kitchen exhaust	kitchen	outside	1900 (4000)	No
9	Canadian Tire	outside	Canadian Tire	2200 (4700)	No
10	Canadian Tire	Canadian Tire	Canadian Tire	820 (1740)	No

TABLE 1: AIR HANDLING UNITS WITHIN THE COMPLEX



Note :

1. Air Handling Unit Number Corresponds to Table I
2. All Dampers Position are Manually Operated

Fig. 4 Air Flow Schematic (Elev)

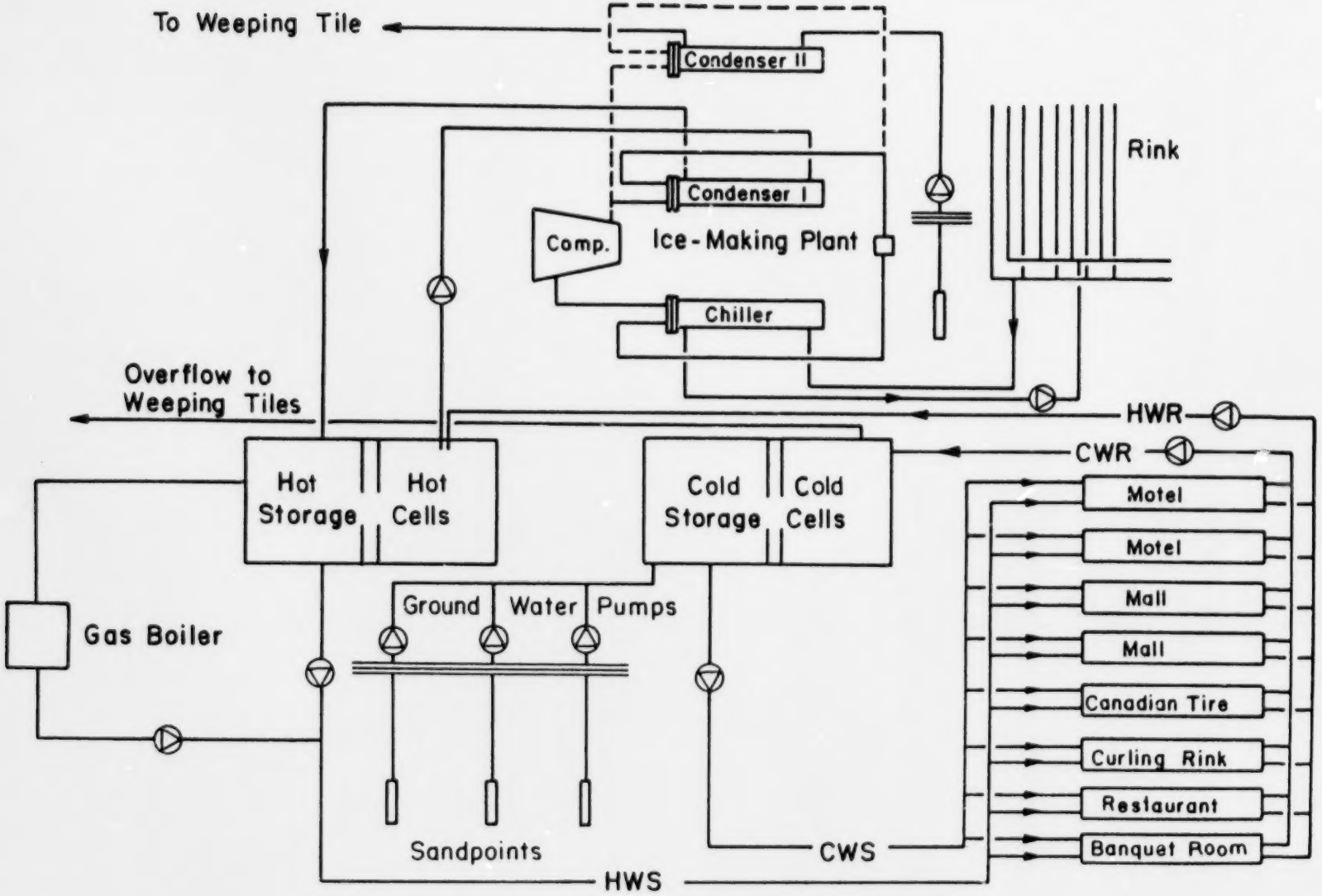


Fig. 5 Mechanical System Schematic

3.3 Existing Electrical System

The electricity is supplied by Manitoba Hydro. There is one meter for all the services in the complex. The electrical supply for the Canadian Tire store is sub-metered from the main service.

A large portion of the electricity is consumed by the lighting and the ice-making plant. Peak consumption and demand, measured in December 1983, were respectively 211 MW·h and 391 kV·A. This occurred when the ice plant (112 kV·A) and the lighting (143 kV·A) were operated simultaneously with some other equipment. The electrical consumption was relatively low during the summer, since there is no central refrigeration for the complex. A demand penalty of 60 kV·A/month was incurred and thus summer bills were based on this amount. Future building retrofitting could take this into consideration and take advantage of the low summer usage and run-off electric rate.

3.4 Present Energy Consumption

The mechanical plant uses electricity and natural gas as energy sources. The monthly breakdown of the energy consumption is shown in Table 2.

The heating plant of the complex operates throughout the year. The consumption of the natural gas for space heating ranged from 15 MW·h in July to 145 MW·h in January, as shown in the PS-A(*) of the DOE-2 report in the Appendix as part of the monthly energy consumption breakdown. Electricity consumption of the complex for cooling and ice-making ranged from 29 MW·h in January to 2.6 MW·h in June.

As indicated in Section 3.2, the indoor swimming pool had a dehumidification load of approximately 0.23 Kg/min (30lb/hr). A conventional dehumidification plant would have consumed approximately 26 MW·h/yr of electricity with a 3.7 kW (5 hp) compressor for a total operation cost of approximately $560/yr. However, the use of ground water for cooling provides almost cost free cooling for this process.

Domestic water heating consumed the equivalent of approximately 190 MW·h of natural gas per year. The loading of this was based on the activity levels in the motel and the food services of the restaurant. Other factors such as ice flooding were considered but appeared to be insignificant compared with the total energy consumption.

(*) PS-A computer designation planned energy utilization (see Appendix A).

MONTH	NATURAL GAS MW·h	ELECTRICITY MW·h	HEATING DEGREE DAYS 1983/84 SI*	HEATING DEGREE DAYS 1976 SI
1983				
AUG	54.2	117.7	5	31
SEP	84.7	145.1	178	160
OCT	88.8	186.3	376	470
NOV	90.8	222.4	581	714
DEC	290.1	211.2	1,171	1,131
1984				
JAN	169.6	198.1	997	1,120
FEB	159.4	174.6	684	860
MAR	187.2	179.2	769	869
APR	116.9	170.4	332	362
MAY	140.6	141.1	265	198
JUN	99.3	144.0	48	47
JUL	63.0	122.8	15	16
TOTAL	1,544.6	2,012.9	5,421	5,979

TOTAL ENERGY CONSUMPTION = 1,546 + 2,013
= 3,559 MW·h

TABLE 2: ACTUAL MONTHLY ENERGY CONSUMPTION FROM BILLING RECORDS

* From Canadian Forces Base, Portage La Prairie.

3.5 Project Plan

The evaluation of the two major energy saving systems of the complex (as described in section 3.2), required a knowledge of the shell losses based on the architectural design of the building, the seasonal activity level in the complex and the operational characteristics of the mechanical plant. A computer simulation method was considered to be the most suitable method for the evaluation of the energy saving systems and other special features.

An analytical evaluation of the energy saved by the mechanical system could have been performed. However, the result would not be accurate considering the dynamic weather changes in Manitoba. Other factors such as energy stored in the system would have been difficult to account for in the analytical calculations. The hour by hour simulation by the computer program was also considered to be more suitable because of these transient conditions.

To use the DOE-2 building energy evaluation program a data base for the existing system was established. All the architectural and mechanical aspects of the facility were included. The activity levels, which affect the energy used for heating the domestic hot water and the internal heat gain, were incorporated. The computer program contained 1976 Winnipeg weather data selected as a typical year for Winnipeg(*) by others. Table 2 shows the actual degree day data for Portage La Prairie in 1983/84, the 1976 data is 10% higher.

An air balance was performed to determine the air distribution -- the quantities of air handled by the air handling units.

The advantage of using DOE-2 was the versatility of the program. All dynamic factors can be included in the evaluation. However, like other computer programs, the results are only as good as the input data. Thus, extreme care was taken in selecting the input data for the program.

After establishing the basic run of the existing facility, other parametric runs could be simulated, and the projected energy consumption accurately evaluated.

(*)Weather tape originally obtained from Unies Ltd. of Winnipeg.

4 PERFORMANCE ANALYSIS AND PROCEDURE

4.1 Preliminary Evaluation of Existing Energy Consumption

A preliminary analysis of the energy consumption of the complex was conducted to establish a base for evaluation and a comparison to other similar establishments. Based on the 1983 invoices the total electricity consumption was 1,545 MW·h (5,272 MBtu) and natural gas of 2,013 MW·h (6,870 MBtu). Monthly breakdown of the energy consumption is shown in Table 2. The facility has a conditioned total floor area of 12,220 m^2 (131,500 ft^2) and an estimated energy consumption index of (1,046 $MJ/m^2/yr$) (27 $kW·h/ft^2/yr$).

A comparison of the energy consumption determined from the utilities bills indicated that the complex consumed about 64% of the energy as a similar facility in Winnipeg. The energy consumption information for similar facilities was based on the energy auditing performed by the Department of Energy and Mines, Province of Manitoba, under the National Energy Audit Program (NEAP). The breakdowns of the energy consumption indices for similar facilities are shown in Table 3. The estimated energy consumption index for similar facilities was 1,640 $MJ/m^2/yr$ (42.4 kW·h/yr) which represented a reduction of 580 $MJ/m^2/yr$ (15 $kW·h/ ft^2/yr$) thus the energy saving systems were effective.

SPACE TYPE	CONDITIONED SPACE AREA m^2 (ft^2)	WEIGHTED AREA %	ENERGY INDEX OF SPACE $MJ/m^2/yr$ ($kW \cdot h/ft^2/yr$)	WEIGHTED ESTIMATED ENERGY INDEX $MJ/m^2/yr$ ($kW \cdot h/ft^2/yr$)
Curling Rink	2320 (25,000)	19.0%	814 (21)	15 (4.0)
Canadian Tire Store	1550 (16,700)	12.7%	2130 (55)	270 (7.0)
Garage	330 (3,550)	2.7%	1920 (49.5)	50 (1.3)
Motel	4740 (51,000)	38.8%	1590 (41)	615 (15.9)
Shopping Mall	3280 (35,300)	26.8%	2050 (53)	550 (14.2)
TOTAL	12,220 (131,500)	100%		1640 $MJ/m^2/yr$ (42.4 $kW \cdot h/ft^2/yr$)

TABLE 3 ESTIMATED ENERGY CONSUMPTION INDEX BASED ON SIMILAR FACILITIES

4.2 DOE-2 Inputs and Operation

To evaluate the energy consumption of the complex using DOE-2, three sets of input data were required. These were load, system and plant components.

The load component of DOE-2 included the architectural features of the complex such as building orientation, insulation level and external and internal shading of the buildings. Other basic items that affect the energy consumption such as equipment load, lighting load and temperature settings in each zone were all incorporated. Thus the load component included all the skin losses of the complex with the required processing load energy consumption.

The result of the load component is transferred to systems component. The systems component simulates the operation of the ventilation and air conditioning systems that distribute cooling and/or heating fluids to the spaces that are conditioned. The control of humidities and temperatures in the spaces are also simulated. The systems component performs two main tasks. It provides information for sizing the units of the various mechanical systems based on the peak load requirements. The program also simulates each distribution system and determines the demand the systems are imposing on the central heating and cooling plant. Information for the system component is transferred to the central plant component for further simulation.

The plant component simulates the primary energy conversion and distribution for heating and cooling. Conventional plant equipment such as boilers and chillers can be simulated. The program can be run with minimal specifications of plant equipment which consists of the size of the equipment, the type and the total number installed. On the other hand, when the actual plant consists of a heat recovery system and storage, more data has to be provided as input. The output of the plant component indicates the recovered energy and the energy utilized by the central plant.

4.3 Site Data Collection

It was necessary to collect accurate data for the computer input and for simulation purposes. Thus, data for the facility and the activities were collected directly by field observations.

In addition to familiarizing, clarifying and understanding the operation of the system, two significant field trips were made on August 1983 and January 1984. These field trips were of prolonged duration to identify the activity level of the complex during summer and winter operation. The complex with both recreational and business functions, has an extreme change of activities with the seasons, which had a direct affect on such factors as domestic hot water consumption (as affected by motel room occupancy) and equipment energy consumption (eg. in kitchen due to increase in the number of meals served). Consequently, based on the business history of the complex and combined with the data collected during the field observations, the input was established. This included:

- occupancy level and schedule
- lighting load and schedule
- equipment load and schedule
- HVAC system schedule
- space thermal conditions

During the field trips, hourly tours around the facility were conducted to determine the above mentioned items. A 48 hour period was required to determine the difference between weekday and weekend conditions.

MONTH	ELECTRICITY DOE-2 MW·h	ELECTRICITY ACTUAL MW·h	ELECTRICITY FRACTION OF ACTUAL	NATURAL-GAS DOE-2 MW·h	NATURAL-GAS ACTUAL MW·h	NATURAL-GAS FRACTION OF ACTUAL
1983						
AUG	132.1	117.7	1.12	60.3	54.2	1.11
SEP	143.6	145.1	0.99	86.5	84.7	1.02
OCT	182.9	186.3	0.98	83.6	88.8	0.94
NOV	185.3	222.4	0.83	82.4	90.8	0.91
DEC	188.7	211.2	0.89	193.0	290.1	0.67
1984						
JAN	185.7	198.1	0.94	237.0	169.6	1.40
FEB	166.0	174.6	0.95	166.0	159.4	1.04
MAR	186.4	179.2	1.04	183.6	187.2	0.98
APR	184.0	170.4	1.08	121.2	116.9	1.04
MAY	155.4	144.1	1.10	130.7	140.6	0.93
JUN	146.5	144.0	1.02	98.8	99.3	1.0
JUL	132.1	122.7	1.08	58.0	63.0	0.92
TOTAL	1988.7	2015.4	0.99	1501.1	1544.6	0.97

$$\text{FRACTION} = \frac{\text{ENERGY PREDICTED BY DOE-2}}{\text{ACTUAL ENERGY CONSUMPTION}}$$

$$\text{TOTAL YEARLY FRACTION} = \frac{\text{TOTAL ENERGY PREDICTED BY DOE-2}}{\text{ACTUAL ENERGY CONSUMPTION}}$$

$$= \frac{1988.7 + 1501.1}{2015.4 + 1544.6} = 0.98$$

TABLE 4 THE DOE-2 RESULT COMPARISON WITH THE ACTUAL CONSUMPTION IN 1983

MONTH	TOTAL HEATING LOAD (DOE-2) MW·h	GAS CONSUMPTION MW·h	WASTE HEAT RECOVERED MW·h	TOTAL ESTIMATED ENERGY LOAD MW·h	WASTE HEAT RECOVERED %
1983					
AUG	9.5	17.7	0.0	18	0
SEP	13.2	22.6	0.0	23	0
OCT	73.9	25.6	59.6	85	70
NOV	133.2	24.0	120.0	144	83
DEC	163.2	105.2	100.4	206	49
1984					
JAN	165.1	145.4	76.0	221	34
FEB	129.4	99.5	69.8	1692	41
MAR	141.0	112.9	73.7	187	39
APR	72.8	33.2	53.6	87	62
MAY	21.4	36.6	0.0	37	0
JUN	11.1	19.9	0.0	20	0
JUL	7.7	15.3	0.0	15	0
TOTAL	1058.9	657.9	553.1	1,212	45.6

Note: Gas consumption includes space heating and domestic hot water heating.
All data extracted from PS-A report from DOE-2 result.

TABLE 5 RECOVERED ENERGY CONTRIBUTION TO HEATING

5 RESULTS AND DISCUSSION

5.1 Establishment of DOE-2 Data Base

After the establishment of the data base of the existing system, further evaluation of potential energy saving features is a matter of modifying the data base. The results are shown in Tables 4 and 5, pages 20 and 21. Table 2 represents the actual monthly energy consumption of natural gas and electricity, obtained from the billing records; the SI heating degree days for 1983/84 and 1976 are also included. The actual energy consumption is for 1983/84 but the DOE-2 program contains 1976 data, which is considered to be a typical meteorological year for Winnipeg. Table 4 compares the actual energy consumption to the results calculated by the DOE-2 simulation for electricity and for natural gas consumption. Table 5 is a record of the estimated energy recovered from the ice-making plant expressed as a fraction of actual gas consumption which includes the energy required for space heating, domestic hot water heating and the swimming pool.

The yearly electrical energy consumption predicted by DOE-2 was 99% of the actual consumption (see Table 3 & 4). The monthly comparison varies from 83% to 112% for November and August respectively. The yearly gas consumption predicted by DOE-2 was 97% of the actual.

The monthly energy consumption predicted by DOE-2 varied from 67% to 140% for December and January respectively. Whereas the degree days for Winnipeg in 1976 were 7% greater than for Portage La Prairie in 1983/84 thus the DOE-2 results could have been as much as 12% low. The major discrepancies occurred in the heavy heating months. However, the differences in degree days between January 1976 (DOE-2) and January 1984 (Actual) was only 11%. The degree days from December 1983 to January 1984 actually decreased by 15% while the total heating load decreased by 41% (290 to 169.6 MW·h) leaving 26% that is attributable to a decreased activity load. It is anticipated that the activity load would be high in December due to holiday activities and unduly low in January because of the aftermath of Christmas. January is reported to be a low activity month by the hospitality industry.

The high DOE-2 predicted energy consumption for January 1984, is still questionable although the winter activity evaluation was based on field observation made during the third week of this month. The only satisfactory explanation is to consider December and January together then the total natural gas consumption predicted by DOE-2

is equivalent to 430 MW·h (1470 MBtu) while the actual consumption is 459.7 MW·h (1570 MBtu), a difference of 6.5%, in keeping with the differences listed for the other months which vary from 7% for May to 11% for August. The results of the data base, therefore are considered to be acceptable.

5.2 Heat Recovery from Ice-Making Plant

The ice-making plant is scheduled to operate from October 15 to April 15 with three compressors with a rated refrigeration capacity of 63.3 kW (18 tons) each. A total of 553 MW·h (1,900 MBtu) is recovered as waste heat by the condenser cooling water. This is equivalent to 45.6% of the total space heating required by the complex. The heating load was taken as the total of the waste heat recovered (553 MW·h/yr) plus the gas consumption (658 MW·h/yr).

The hot water recovered from the ice-making plant condenser is returned to the hot water storage tanks. A secondary gas fired hot water boiler of 47.8 kW (16.3 MBtu/h) heating capacity boosts the temperature of the water to a suitable temperature for space heating (refer to Fig. 5 for system layout).

The ice-making plant was simulated by the computer model as a double bundle chiller with the same rated refrigeration capacity of 190 kW (54 tons). The hot water tank was estimated to have approximately 19.3 MW·h (66 MBtu) of heat storage capacity. In the simulation, the heat energy recovered from the plant was used to supplement the space heating load.

The monthly breakdown of the heating load, the gas consumption for heating and the waste heat recovered is shown in Table 5. (This result is extracted from the PS-A(*) report of the DOE-2 results). At an equivalent unit cost of \$0.0152/kW·h (\$4.45/MBtu) for natural gas which the Westward complex was paying in 1983 and a utilization efficiency of 68%. Although the existing heating plant was evaluated to operate at 59% efficiency, a 68% efficiency was used for cost evaluation as described in Section 5.4, this was primarily due to the fact that without the heat recovery system, the existing heating

(*) PS-A computer designation planned energy utilization, (see Appendix A).

plant would have operated at a higher capacity resulting in the better efficiency. The value of the recovered heat was estimated to be $12,000/yr. Such a heat recovery system was demonstrated to be effective during the winter because its availability coincided with the space heat load. The hot water storage tank was not essential for the heat recovery system. According to the PS-C(*) report of DOE-2, annually there is only 31.1 MW·h (106 MBtu) of heat released from the storage tank compared to 553 MW·h (1890 MBtu) of recovered waste heat. Therefore, energy recovered from the ice-making plant could be utilized directly for heating purposes with minimal or no storage because of the size of the complex, which has a high energy demand for space heating.

The swimming pool water was considered for waste heat storage. Because of the recreational nature of the pool, the temperature of the water can not be allowed to fluctuate more than 3°C (5°F), which limits the storage capacity to 280 kW.h (0.96 MBtu). The result of the simulation indicated that this reduced storage would provide only 3.2 MW·h (11 MBtu) of space heat. For this system the recovered heat would be reduced to 525 MW·h (1,793 MBtu) from the current 553 MW·h (1,890 MBtu) provided by the existing system, a reduction of 5%. Thus, with careful monitoring of water temperature, the swimming pool water would provide adequate storage for this complex.

The simulation demonstrates the application of recoverable heat from an ice-making plant when the heat load occurs at the same time. This is applicable to most indoor ice rinks located in northern latitudes and operated during the winter season.

PS-C(*) equipment load operation DOE-2 printout (see Appendix A).

5.3 Ground Water Cooling

Three sand point stations provide about 4.5 L/s (60 gpm) of ground water for cooling during the summer season. Total cooling energy utilized is 636 MW·h (2,170 MBtu) as indicated from the PS-B of DOE-2 report. The operating cost of this ground water due to the sandpoint pumping power and of equipment is almost negligible.

The actual cooling system consisted of three sand point stations that feed ground water into the storage tanks. The ground water temperature ranged from 10°C (50°F) to 16°C (61°F), an average ground water temperature of 12°C (54°F) was calculated for computer input data. Ground water that feeds into the storage tank is redistributed into different areas that require air conditioning. Overflow of the storage tank, recorded to be about 8°C (64°F), was returned back to underground.

Based on the total of 4.5 L/s (60 gpm) of ground water and a temperature difference of 5.6°C (10°F) in between the supply and return water, the cooling capacity of the ground water from the storage tank was estimated to be 105 kW (30 tons). Again based on the same temperature difference and a total of 450,000 L (100,000 gal) storage capacity for the tank, a thermal storage of 2.9 MW·h (10 MBtu) was input into the system.

Cooling Capacity Evaluation:

Based on the water inlet temperature of 12.2°C (54°F) and a water outlet temperature of 17.8°C (64°F),

$$\text{the capacity} = \dot{m}Cp\Delta T$$
$$= (60 \times 10) \times 1 \times 10/56.9$$
$$= 105 \text{ kW (30 tons of refrigeration).}$$

Cooling Tank Thermal Storage Capacity:

Total storage of 450,000 L (10,0000 gal) with a temperature difference of 5.°C (10°F) provide the following thermal storage capacity:

$$\text{capacity} = M\ Cp\Delta T$$
$$= (100{,}000 \times 10) \times 10/3413 = 2.9 \text{ MW·h.}$$

Where: $\dot{m}$ = Mass flow rate,
M = Mass of the storage,
Cp = Specific heat,
ΔT = Temperature difference.

The ground water was simulated as chilled water that the complex had purchased from outside. The unit cost of the purchased chilled water was input as zero, i.e. free cooling. The rate at which the chilled water was supplied to the complex was input as 105 kW, the same rate as the ground water cooling. A storage tank of equal capacity was simulated in the program.

The use of ground water for cooling during summer was demonstrated to be practical and cost effective. The estimated annual cooling load was approximately 636 MW·h. Using a coefficient of performance of three of a conventional refrigeration plant, the use of ground water for cooling saved about 212 MW·h of electricity. Based on the 1983 electricity cost, the implementation of ground water saves approximately $2,620/yr, which is calculated as follows:

Using 1983 electricity rates:	
Demand Charge	= $5.2/kV·A/month
electricity run-off rate	= $0.01237/kW·h
Existing ground water cooling rate (with a COP of the refrigeration plant of 3)	= 190 kW (54 ton)
Electricity consumption = 636 MW·h/3	= 212 MW·h
Total Saving = $0.01237 x 212,000	= $2,620/yr

No demand saving was imposed on the ground water cooling. The demand cost during the summer period was primarily due to the demand penalty of the winter ice-making plant. The ice-making plant with 3 - 26kW compressors imposed a demand penalty of 62.4 kW for the rest of the year. A refrigeration plant with 105 kW (30 tons) capacity would require approximately the same electrical demand and thus the same demand cost would be paid regardless of the operation of the refrigeration plant during the summer period.

Approximately 349 MW·h (1,192 MBtu) of ground water cooling capacity was stored in the 450,000 L (100,000 gal) tanks which was equivalent to about 55% of the total cooling load. This was primarily due to the storing of the ground water during the early morning period when less cooling was required and then utilizing the stored capacity during the remainder of the day when there was a higher demand. It was estimated that the initial marginal cost of storage tanks was of the order of $10,000, which with the estimated savings of $2,620/year would be covered within 5 years.

5.4 Complex Without Energy Conservation

Simulating the existing complex without the energy conservation features indicated a gas and electricity consumption of 2,240 MW·h (7,633 MBtu) and 2,250 MW·h (7,680 MBtu) respectively. This was an increase of 49% in the consumption of gas and 13.2% in the consumption of electricity over the base simulation which included the main energy conservation systems.

The total energy consumption of the facility without energy saving features is indicated in PS-B (*) report as 4,480 MW·h (15,300 MBtu). This corresponds to an energy consumption index of 1330 $MJ/m^2/yr$ (34.3 $kW·h/ft^2/yr$). This index is different from the 1,640 $MJ/m^2/yr$ (42.4 $kW·h/ft^2/yr$), the estimated consumption index, from Table 3 which was determined by summing the weighted area percent of the energy consumption index of the different types of spaces within the complex. The computer simulation which is based on the architectural features and the annual processing load profiles, is considered to be a more accurate prediction of the energy consumption than the estimates based on similar facilities in other locations.

Energy consumption of the existing plant (with energy recovery system)	= 3,914 MW·h/yr
Energy consumption of a conventional plant (without energy recovery system)	= 4,490 MW·h/yr
Difference	= 574 MW·h/yr

The saving indicated was less than that of the total recovered energy of 765 MW·h (2,600 MBtu) (212 MW·h from cooling and 553 MW·h from heating). This is due to the oversize of the existing boiler which only operated up to 50% of rated capacity, while the same plant without a heat recovery system would operate up to 70% of its capacity. The difference of the heating load demand resulted in the existing boiler operating at an estimated efficiency of 59% while the same plant may have operated at an efficiency as high as 68% at 70% of rated capacity. This indicates the importance of correctly sizing the HVAC equipment, as the operating efficiency is extremely sensitive to load.

(*) PS-B computer designation for monthly peak and total energy use (see Appendix).

5.5 Installation of Air Type Solar System on the South Facing Wall of the Curling Rink

Low cost solar collectors are more cost effective than expensive high performance flat plate collectors for space heating purposes. In the winter months a vertical mounted collector will be exposed to at least 85% of the solar radiation that a rigidly mounted collector at a more optimal inclined angle will see. Thus two variations of a low cost air collector fabricated on the 185 m^2 (2000 ft^2) south wall of the rink were evaluated.

By fastening to the existing light coloured wall, with an absorptivity (α) of 0.5, a corrugated fibreglass reinforced plastic or kalwall cover plate, with a transmissivity of (τ) 0.9, yielded curve A. Using this retrofit to preheat supply air as shown in Fig. 6 the estimated heat recovered from this system was 34 MW·h/yr (116 MBtu/yr) providing an approximate saving of only $880/yr.

Painting the wall black, an absorptivity of 0.85 could be obtained and a similar cover plate (i.e. $\tau\alpha = 0.77$), curve 'B' (Fig. 7) yielded an estimated yearly heat recovery of 47.9 MW·h (165 MBtu/yr) when used to preheat air or a saving of only $1,200/yr.

The estimated cost of field erecting these low cost systems was between $108 and $160/$m^2$ ($10 and $15/$ft^2$), that is an initial installed cost of between $20,000 and $30,000. The energy saved at low unit cost of $0.028/KW·h ($7.55/MBtu) would not cover the carrying charges. The estimated performance curves are shown in Fig. 7 along with a high performance air collector such as a Lennox or Minneapolis Honeywell double glazed well insulated model.

The use of the collector for air preheating was considered the best application since the temperature difference between the incoming fluid (T_i) and the surroundings (T_a) is small. Then for a given solar intensity (I) the collector efficiency will be relatively high.

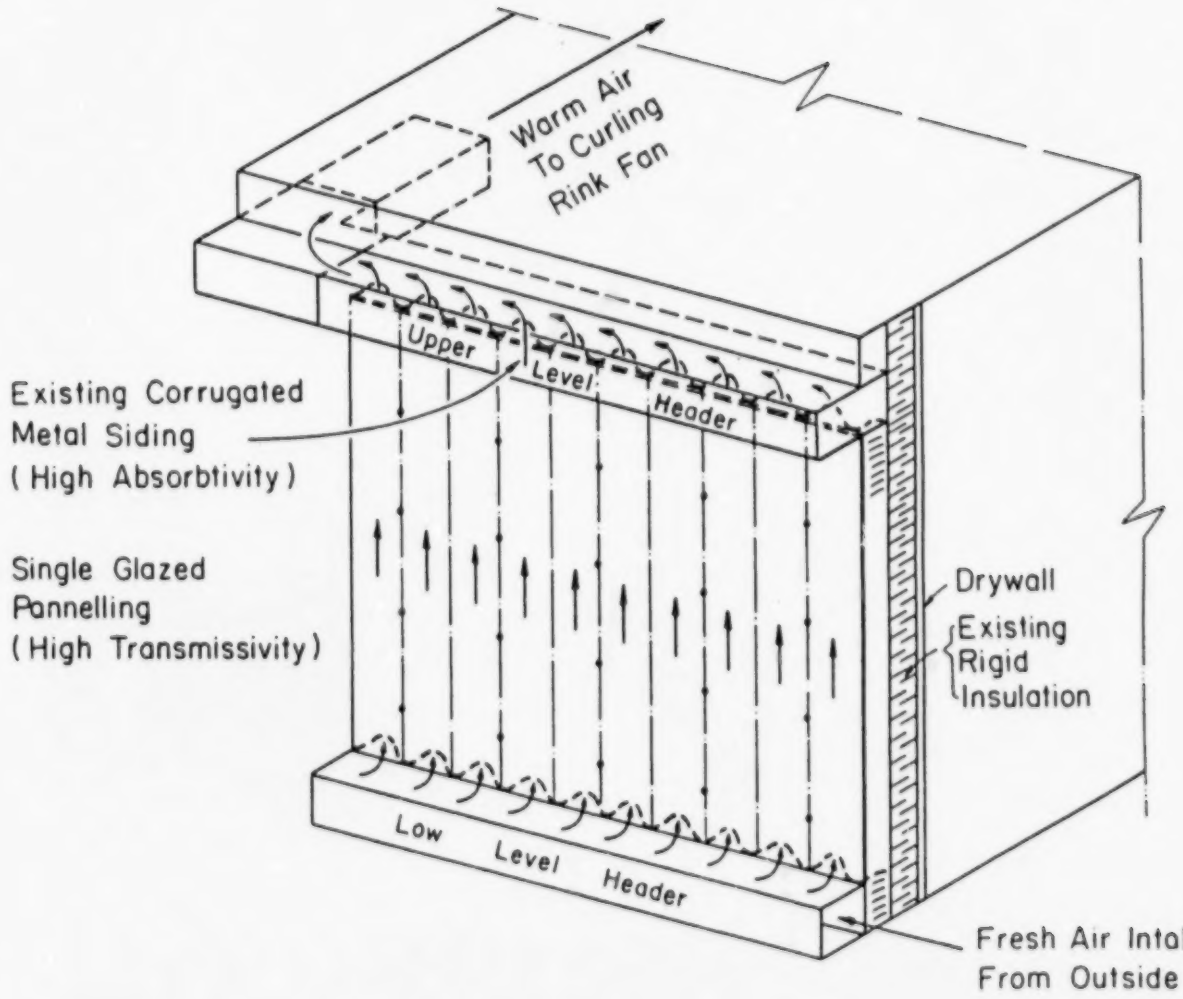


Fig. 6 Solar Panel Construction Layout

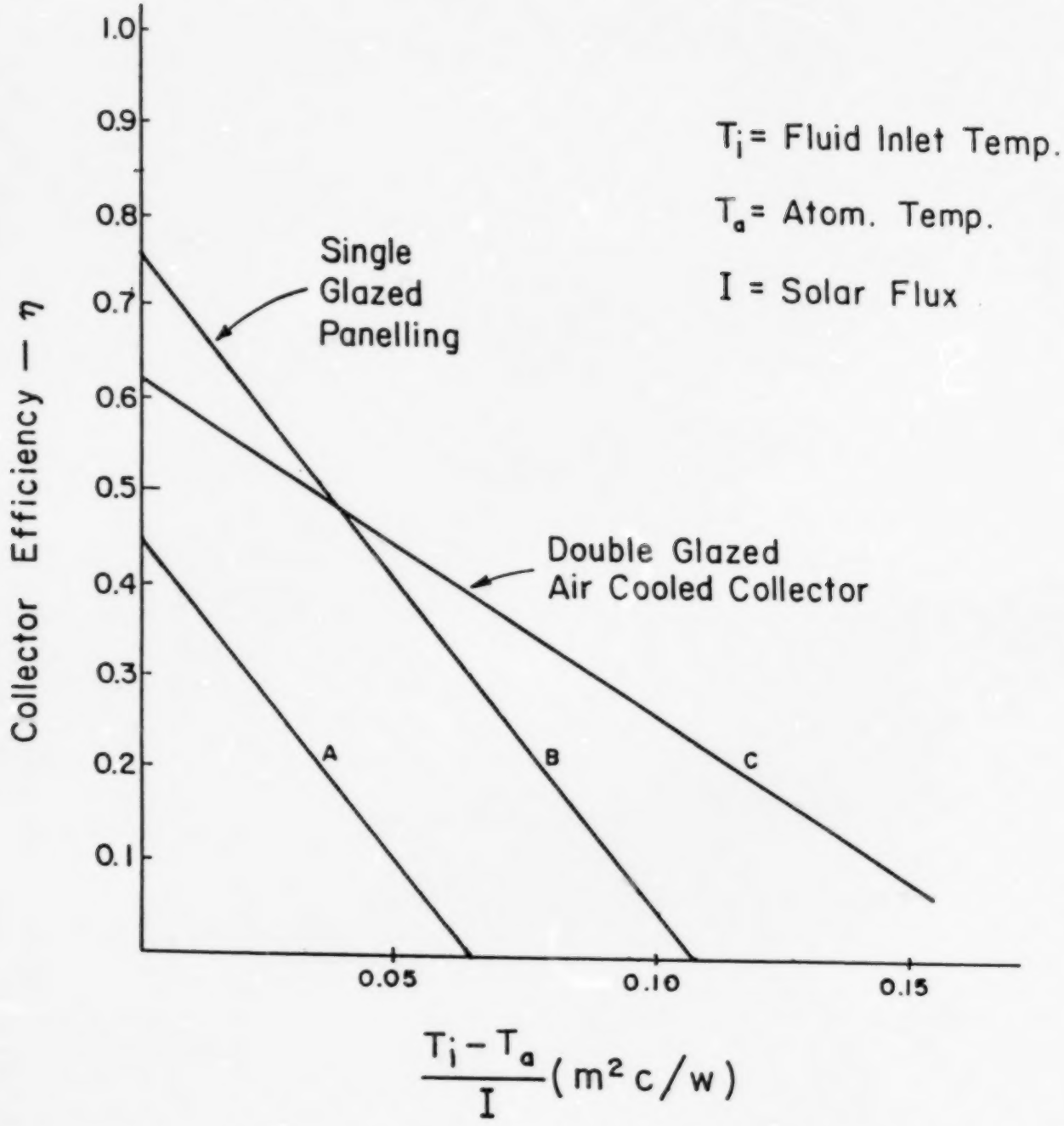


Fig. 7 Estimated Thermal Efficiency of the Solar System Installed on the South Facing Wall of Curling Rink

5.6 Existing Plant With Heat Recovery Systems on Ventilation Exhaust Air

This parametric run was based on the installation of three heat recovery systems on the ventilation units of the motel banquet room, the kitchen and the Canadian Tire store. The total energy saving indicated from the simulation model is 146 MW·h/yr (500 MBtu/yr) or a saving of $3,800 (using 1983 natural gas costs).

The three recovery systems mentioned above have exhaust air of 940, 520 and 820 L/s respectively. A heat recovery effectiveness of 50% was allowed in the model. All the energy recovered was designated for preheating the fresh air supply. The fictitious systems were assumed to have a 12 month operation period, and their respective operation schedule corresponded to the fan schedule (manually controlled) and the requirements of space heating of the complex.

The implementation cost of this heat recovery system was estimated to be about $22,000. This corresponded to high $9.6/L/s ($4.5/cfm) of exhaust air. The relatively high estimated cost of the installation was due to the decentralized exhaust systems. The kitchen reclaim system would require a special washdown module for grease removal from the coil.

5.7 Conversion of Central Heating Plant to Electric Heat

The purpose of this parametric analysis was to determine the effect of using electric heat. The same mechanical system was maintained with the same rated capacity for each component of the equipment. The only difference was to change the boilers from gas to electric heat.

Using 1983 electrical rates, the result of the simulation indicated a saving of 196 MW·h of energy consumption but an increase of $2,800/yr in utility costs. The energy saving was expected as previous evaluations indicated that the existing boiler operated at 59% efficiency while electric heating is 100% efficient. The increase of utility cost was primarily due to the demand penalty imposed by the winter operation. A total of 637

kV·A of demand penalized the rates from May to October, at a unit penalty cost of $5.2/kV·A, which resulted in a demand penalty cost of $3,300/yr.

A new interruptible electric rate was introduced in 1984, which was applicable for a facility with more than 500 kV·A of process and space heating load. However, the existing complex, even with the conversion from gas to electric heating, had a peak demand of less than 500 kV·A and thus the interruptible rate was not applicable.

5.8 Automatic Control System

An automatic control system for positioning fresh air and return air dampers was considered. Normally, most air handling units are arranged so that when the outside temperature is between 13°C (55°F) and 16°C (60°F) the fresh air damper is fully opened for cooling purposes. However, for the Westward Village Inn complex, with ground water for cooling, this procedure is not particularly advantageous.

For winter heating operation, it is advisable to operate with a minimum quantity of fresh air for energy conservation purposes. Thus an automatic damper could only be used to provide some predetermined minimum amount of supply air. Other automatic control systems, which switch from a heating to a cooling mode for an air handling unit would have little bearing on energy conservation. Such an automatic system, however, would eliminate manual procedures. A solenoid control valve would be required for each coil, so that the valve would respond to an outside air temperature sensor, and a switch for initiating heating or cooling mode.

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the results of this investigation of the Westward Village Inn complex it is concluded that:

(1) The implementation of a system to recover the heat from the curling rink ice-making plant in Westward Village Inn complex, Portage La Prairie, Manitoba has been demonstrated to be practical and cost effective.

(2) The use of the hot water storage tanks for the Westward Village Inn complex was not necessary since the large space heating load utilized the waste heat as it was produced by the ice-making plant.

(3) The use of ground water for summer cooling of the buildings with a substantial amount of storage proved practical and cost effective in this case.

(4) The adaptation of the south wall of the curling rink to form a low cost air solar collector for air preheating would be the most cost effective method of utilizing solar energy, but such methods still have unacceptable payback periods based on the current cost of other forms of energy in Manitoba.

(5) Since the electrical demand penalty is substantial for most rink applications the use of the cheap electricity at run-off rates should be considered for summer applications.

(6) The use of heat recovery equipment on the exhaust ventilation air appeared to be cost effective. However in this case a run-a-around or coil-to-coil loop type of heat exchanger would probably be required because the supply inlets are generally remote from the exhaust outlets. Frosting of air-to-air heat exchangers may also reduce the overall effectiveness for rinks and swimming pool exhaust applications.

(7) The use of electric heating increased the demand penalty cost and the peak demand was insufficient to make use of Manitoba Hydro's interruptible rates. Thus the use of electric heating was not economical based on 1983 energy rates.

(8) An automatic control system which would consist of individual damper controls, while convenient, would not prove to be cost effective.

6.2 Recommendations

(1) For an indoor rink it is recommended that the waste heat available from the ice-making plant be utilized for heating applications. If the heat load is large relative to the waste heat available, minimal storage is required. In any case a careful analysis of storage requirements should be made. The use of waste heat from refrigeration plants is applicable for spacing heating of associated recreational centres, and sub-floor heating in rinks or cold storage plants to prevent floor heaving, particularly for a year-round operation.

(2) The use of ground water for cooling is economically attractive if the water table is not too low and if the cost of the storage can be shared with some other structural building function. It is recommended that a careful engineering cost analysis be made before proceeding with an installation involving any form of ground water cooling system. The system is comprised of, a natural water reservoir at a low temperature (10°C or 50°F), a pumping station, a storage facility and a cooling load. Thus an optimization is required to establish the appropriate size of the components.

(3) If an ice-making plant is only used for five or six months of a year it is recommended that a means of controlling the electrical demand charges incurred should be investigated. An alternative is to use the plant for summer cooling using the electrical run-off rate which was $0.0127/kW·h in Manitoba in 1983.

(4) It is recommended that the heating plant be sized, taking into account the contribution of waste heat recovery.

(5) It is recommended that consideration be given to heat recovery from the exhaust air if a large volume of ventilation air is required. The unit cost of energy in Canada is increasing to the point where payback periods on heat recovery equipment are becoming acceptable.

REFERENCES

(1) American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. ASHRAE HANDBOOK 1982 Applications.

(2) American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. ASHRAE HANDBOOK 1977 Fundamentals.

(3) Building Energy Simulation Group, DOE-2 Supplement (Version 2.1B). Energy and Environment Division, Lawrence Berkeley Laboratory, Berkeley, California (1983).

(4) U. S. Department of Housing and Urban Development. Intermediate Minimum Property Standards for Solar Heating and Domestic Hot water Systems. Washington, D.C. Energy, Building Technology and Standards Division, 1976.

(5) University of Manitoba. Gerhardt Schmidt. Energy Consumption Simulation and Verification of Large Metered Building with DOE-2.1A and DOE 2.1B Solar Energy Society of Canada Inc., Sunfest '83, 1983.

(6) Solar Energy Group, Group Q-11, DOE-2 Reference Manual. Los Alamos National Laboratory, Los Alamos, NM 67545 (1981).

APPENDIX A

DOE-2 RESULTS

BUILDING ENERGY CONSUMPTION ANALYSIS — WESTWARD INN & CURLING RINK COMPLEX. — DOE-2.1B — 9/28/84 — 10:39 PM — PDL RUN 1
OFFICE OF INDUSTRIAL RESEARCH, — GEORGE CHAN (204)474-8292 — MECHANICAL SYSTEM INPUT
REPORT- PS-A PLANT ENERGY UTILIZATION SUMMARY

	SITE ENERGY											SOURCE
	2	3	4	5	6	7	8	9	10	11	12	13	14
MONTH	TOTAL HEAT LOAD	TOTAL COOLING LOAD	TOTAL ELECTR LOAD	RCVRED ENERGY	WASTED RCVRABL ENERGY	HEAT INPUT COOLING	ELEC INPUT COOLING	FUEL INPUT HEATING	ELEC INPUT HEATING	FUEL INPUT ELECT	TOTAL FUEL INPUT	TOTAL SITE ENERGY	TOTAL SOURCE ENERGY
JAN	563.7	169.8	633.9 185.7E	259.4	0.0	0.0	98.9 29.0E	496.1	26.1 7.8E	0.0	606.9	1442.9	2985.1
FEB	441.4	156.4	586.7 186.0E	236.2	0.0	0.0	90.0 26.4E	339.7	18.7 5.5E	0.0	586.6	1133.2	2494.0
MAR	481.4	183.3	635.3 186.1E	251.7	0.0	0.0	97.5 28.6E	385.4	21.5 6.3E	0.0	626.7	1262.0	2787.6
APR	248.5	389.6	628.1 184.0E	183.1	73.6	0.0	69.2 20.1E	113.2	5.5 1.6E	0.0	413.8	1226.8	2919.9
MAY	73.2	393.2	530.4 155.4E	0.0	0.0	0.0	9.1 2.7E	124.8	5.0 1.5E	0.0	446.2	1389.6	3036.9
JUN	37.9	432.3	500.0 146.5E	0.0	0.0	0.0	8.6 2.6E	87.8	0.5 0.1E	0.0	337.1	1269.4	2902.5
JUL	26.2	353.5	450.9 132.1E	0.0	0.0	0.0	9.1 2.7E	52.1	0.1 0.0E	0.0	197.9	1002.3	2438.6
AUG	32.3	349.8	450.9 132.1E	0.0	0.0	0.0	9.1 2.7E	80.4	0.1 0.0E	0.0	208.7	1007.4	2440.0
SEP	44.9	332.2	490.0 143.6E	0.0	0.0	0.0	8.6 2.5E	77.1	0.3 0.1E	0.0	295.1	1117.4	2826.4
OCT	252.3	348.2	624.4 182.9E	203.4	105.3	0.0	105.8 31.0E	87.5	4.3 1.3E	0.0	285.3	1034.8	2859.4
NOV	494.5	289.5	632.5 185.3E	403.4	13.1	0.0	136.1 39.9E	61.9	4.4 1.3E	0.0	281.4	913.9	2432.6
DEC	556.9	236.5	643.9 188.7E	342.6	0.0	0.0	115.2 33.7E	359.1	19.6 5.7E	0.0	658.8	1302.7	2869.0
	3213.0	3804.3	6787.0 1988.8E	1887.7	192.1	0.0	777.5 227.8E	2245.1	106.1 31.1E	0.0	5124.5	14082.6	32551.9

NOTE-- ALL ENTRIES ARE IN MBTU EXCEPT
ENTRIES FOLLOWED BY E ARE IN MWH (THOUSANDS OF KWH)

BUILDING ENERGY CONSUMPTION ANALYSIS — WESTWARD INN & CURLING RINK COMPLEX. — DOE-2.1B — 9/28/84 — 10:39 PM — PDL RUN 1
OFFICE OF INDUSTRIAL RESEARCH, — GEORGE CHAN (204)474-8292 — MECHANICAL SYSTEM INPUT
REPORT- PS-B MONTHLY PEAK AND TOTAL ENERGY USE

MO	UTILITY-	STEAM	CHILLED-WATER	ELECTRICITY	NATURAL-GAS
JAN	TOTAL(MBTU)	0.000	0.000	633.508	806.945
	PEAK(KBTU)	0.000	0.000	1276.176	2172.793
	DY/HR	31/21	31/24	2/12	27/16
FEB	TOTAL(MBTU)	0.000	0.000	586.671	586.574
	PEAK(KBTU)	0.000	0.000	1276.367	1816.421
	DY/HR	28/20	28/24	3/12	3/12
MAR	TOTAL(MBTU)	0.000	0.000	635.317	626.897
	PEAK(KBTU)	0.000	0.000	1286.398	1870.897
	DY/HR	31/24	31/24	10/12	2/ 9
APR	TOTAL(MBTU)	0.000	184.887	626.060	413.818
	PEAK(KBTU)	0.000	6932.198	1491.430	1048.484
	DY/HR	28/ 8	23/ 3	14/12	20/ 8
MAY	TOTAL(MBTU)	0.000	393.238	630.352	446.200
	PEAK(KBTU)	0.000	6932.198	1080.384	1202.855
	DY/HR	25/ 8	31/ 3	6/ 9	6/ 9
JUN	TOTAL(MBTU)	0.000	432.348	500.036	337.042
	PEAK(KBTU)	0.000	6932.198	1062.320	776.908
	DY/HR	30/19	30/ 3	4/12	18/24
JUL	TOTAL(MBTU)	0.000	383.488	450.880	197.842
	PEAK(KBTU)	0.000	6932.198	874.386	378.826
	DY/HR	12/ 8	31/ 3	10/12	17/ 8
AUG	TOTAL(MBTU)	0.000	348.788	450.822	208.888
	PEAK(KBTU)	0.000	6932.198	876.089	412.421
	DY/HR	31/18	31/ 3	28/12	30/ 8
SEP	TOTAL(MBTU)	0.000	332.230	490.031	295.128
	PEAK(KBTU)	0.000	6932.198	1037.386	688.345
	DY/HR	28/23	30/ 3	23/10	27/16
OCT	TOTAL(MBTU)	0.000	125.215	624.351	285.278
	PEAK(KBTU)	0.000	6932.198	1436.228	851.041
	DY/HR	16/24	5/ 3	16/12	28/ 8
NOV	TOTAL(MBTU)	0.000	0.000	632.535	281.380
	PEAK(KBTU)	0.000	0.000	1331.110	1200.022
	DY/HR	30/24	30/24	3/12	30/ 8
DEC	TOTAL(MBTU)	0.000	0.000	643.927	658.738
	PEAK(KBTU)	0.000	0.000	1298.836	1804.672
	DY/HR	31/24	31/24	1/12	22/10

(CONTINUED)

UTILITY-	STEAM	CHILLED-WATER	ELECTRICITY	NATURAL-GAS
ONE YEAR	0.000	2171.203	8787.011	5124.411
USE/PEAK	0.000	8.932	1.481	2.173
YEAR COST (K$)	0.0	0.0	52.3	23.5
COST ESCLTN (PCT)	5.0	5.0	0.0	0.0

TOTAL YEAR USE (MBTU) 16082.626
TOTAL YEAR COST (K$) 75.7

NOTE -- YEAR COST IS IN CURRENT $DOLLARS

EQUIPMENT	HOURS AT PERCENT PART LOAD RATIO											TOTAL HOURS	ANNUAL LOAD (MBTU)	FALSE LOAD (MBTU)	ELEC USED (MBTU)	THERMAL USED (MBTU)
	0 -- 10	-- 20	-- 30	-- 40	-- 50	-- 60	-- 70	-- 80	-- 90	-- 100	- 110+					
HW-BOILER	2027	1155	1084	213	28	0	0	0	0	0	0	4517	990.5	0.0	82.7	1586.3
	2027	1155	1084	213	28	0	0	0	0	0	0					
DHW-HEATER	7244	1516	0	0	0	0	0	0	0	0	0	8760	334.3	0.0	0.0	847.7
	7244	1516	0	0	0	0	0	0	0	0	0					
BBUN-CHLR	0	0	11	1458	836	862	483	344	85	70	471	4388	1432.7	0.0	850.5	0.0
	0	0	11	1458	836	862	483	344	85	70	471					
COOLING-TWR	248	113	134	358	103	43	8	2	0	0	0	900	195.2	0.0	19.8	0.0
	248	113	134	358	103	43	8	2	0	0	0					
HTANK-STORAGE	0	0	0	0	0	0	0	0	0	0	0	0	0.0	0.0	0.0	108.1
	0	0	0	0	0	0	0	0	0	0	0					
CTANK-STORAGE	0	27	295	428	321	132	48	20	30	37	2781	4034	1171.1	0.0	0.0	1192.3
	4034	0	0	0	0	0	0	0	0	0	0					

HOT LOOP CIRCULATION PUMP ELECTRICAL USE = 23.4 MBTU
COLD LOOP CIRCULATION PUMP ELECTRICAL USE = 107.1 MBTU

NOTES TO TABLE
1) THE FIRST PART LOAD ENTRY FOR EACH PIECE OF EQUIPMENT IS THE HOURLY LOAD DIVIDED BY THE HOURLY OPERATING CAPACITY

2) THE SECOND PART LOAD ENTRY FOR EACH PIECE OF EQUIPMENT IS THE HOURLY LOAD DIVIDED BY THE TOTAL INSTALLED CAPACITY

TOTAL HOURS AT HOURLY DEMAND AND TIME OF DAY

	HOUR	1AM	2	3	4	5	6	7	8	9	10	11	12	1PM	2	3	4	5	6	7	8	9	10	11	12	TOTAL
	444	0	0	0	0	0	0	0	0	23	25	25	25	0	0	0	0	0	0	0	0	0	0	0	0	98
	405	0	0	0	0	0	0	0	25	11	11	8	46	0	0	0	0	0	0	0	0	0	0	0	0	101
	375	0	0	0	0	0	0	0	78	117	115	115	83	11	12	11	12	0	12	12	12	12	0	0	0	804
	341	0	0	0	0	0	0	0	46	86	86	86	86	15	14	15	14	25	17	19	19	19	29	14	14	533
D	307	0	0	0	0	0	0	0	17	99	106	106	117	131	211	209	215	184	127	125	128	128	9	19	19	1944
E	273	0	0	0	0	0	0	0	117	15	11	11	0	150	70	72	86	87	84	84	83	105	144	150	150	1352
M K	239	51	46	0	0	0	0	0	51	15	15	15	15	2	3	3	3	2	80	80	80	40	117	98	98	826
A W	204	130	137	0	0	0	0	17	6	11	11	11	11	39	44	44	44	45	85	85	85	83	22	23	23	836
N	170	0	0	28	28	21	20	165	19	0	0	0	0	0	17	11	11	11	10	10	10	10	44	82	82	556
D	136	23	21	148	154	161	162	28	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	887
	102	181	181	75	75	75	75	157	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	783
	68	0	0	107	107	107	107	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	428
	34	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	PERCENT TOTAL DEMAND	2.7	2.7	1.9	1.8	1.8	1.8	2.3	5.3	5.9	5.9	5.9	6.0	4.8	4.9	4.9	4.9	4.8	4.7	4.7	4.7	4.8	4.4	4.3	4.2	

PEAK ELECTRICAL LOAD BREAKDOWN

SOURCE	KW	PCT
SYSTEMS LOAD	355.331	81.3
CIRCULATION PUMPS	4.777	1.1
DBUN-CHLR	69.095	15.8
COOLING-TWR	7.786	1.8
TOTAL	436.989	

ENERGY TYPE IN SITE MBTU - STEAM	CHILLED-WATE	ELECTRICITY	NATURAL-GAS	RECOVERED
CATEGORY OF USE				
SPACE HEAT 0.00	0.0	82.78	3028.18	1781.28
SPACE COOL 0.0	2171.20	721.43	0.0	0.0
HVAC AUX 0.0	0.0	1827.84	0.0	0.0
DOM HOT WTR 0.0	0.0	0.0	847.70	0.0
AUX SOLAR 0.0	0.0	0.0	0.0	0.0
LIGHTS 0.0	0.0	3732.80	0.0	0.0
VENT TRANS 0.0	0.0	0.0	0.0	0.0
MISC EQUIP 0.0	0.0	1470.52	1446.51	0.0
TOTAL 0.00	2171.20	7835.37	5122.37	1781.28

NOTE ABOVE FIGURES DO NOT INCLUDE THE 31.00 MBTU RESIDUAL IN THE HOT STORAGE TANK

TOTAL SITE ENERGY 14082.81 MBTU 91.1 KBTU/SQFT-YR GROSS-AREA 91.1 KBTU/SQFT-YR NET-AREA
TOTAL SOURCE ENERGY 32581.00 MBTU 210.8 KBTU/SQFT-YR GROSS-AREA 210.8 KBTU/SQFT-YR NET-AREA

PERCENT OF HOURS ANY SYSTEM ZONE OUTSIDE OF THROTTLING RANGE = 89.3
PERCENT OF HOURS ANY PLANT LOAD NOT SATISFIED = 0.0

NOTE ELECTRICITY AND/OR FUEL USED TO GENERATE ELECTRICITY IS APPORTIONED BASED ON THE YEARLY DEMAND. ALL OTHER ENERGY TYPES ARE APPORTIONED HOURLY.

REPORT PS-A — PLANT ENERGY UTILIZATION SUMMARY

Column 1 — MONTH

Columns 2 to 13 — SITE ENERGY
The information in these 12 columns is site energy use in GBTU (10^9Btu). For electrical energy the entry followed by an E is the energy in GWH (millions of kWH).

Column 2 — TOTAL HEAT LOAD
If there is no absorption chiller, storage tank, or no steam turbine, these values are identical to those in the SYSTEMS SS-D report, with the addition of circulation loop losses, circulation pump energy, and hot water loads from LOADS. The total heating load can be described either in terms of the use of heat or in terms of the source of that heat. Thus total heating load = load fro LOADS + load from SYSTEMS + load from PLANT (i.e., absorption chillers + steam turbines + heat dissipated from storage tank + heat stored in tank, but not used + circulation loop losses + circulation pump energy). Alternatively total heat energy = boiler output + recovered heat + solar heat + purchased steam + loads-not-met.

Column 3 - TOTAL COOLING LOAD
These values are the same as the values reported in the SS-D Report with the addition of tank and circulation loop losses and circulation pump energy and represent the cooling energy needed each month.

Column 4 — TOTAL ELECTR LOAD
This is the total electrical energy consumed by lights, equipment, and system fans plus the additional energy consumed by chiller motors, pumps, cooling towers and any other electrical site use.

Column 5 - RCVRED ENERGY
The values in this column are for the recovered heat that is used to reduce heating loads. The recovered heat is the waste heat from turbines, diesels, and double bundle chillers plus any solar energy used by PLANT through the HEAT-RECOVERY command.

Column 6 — WASTED RCVRABL ENERGY
The values in this column represent the heat that could have been recovered, if there had been a need for it, but was rejected in the absence of a demand.

Column 7 — HEAT INPUT COOLING
This column reports the heat energy used to drive absorption chillers.

Column 8 — ELEC INPUT COOLING
This column reports the electric energy used to drive refrigeration units and to supply power for peripheral cooling equipment, such as circulation pumps, cold storage tanks and the cooling tower.

Column 9 - FUEL INPUT HEATING
This column reports the fuel used for heating by the boilers, furnaces, and domestic hot water heaters.

Column 10 — ELEC INPUT HEATING
This column reports the electrical energy used in association with supplying heating. This includes the electrical consumption by draft fans, circulation pumps, electric boilers, and hot water storage pumps.

Column 11 — FUEL INPUT ELEC
This column reports the fuel used by diesel and gas turbine electric generators.

Column 12 — TOTAL FUEL INPUT
This column reports the total fossil fuel used by all equipment entered in LOADS, SYSTEMS or PLANT. Included, therefore, are process equipment entered through the SOURCE-TYPE and related keywords in LOADS, through the BUILDING-RESOURCE instruction in LOADS, as well as oil or gas furnaces simulated in SYSTEMS and any equipment in PLANT.

Column 13 — TOTAL SITE ENERGY
This column reports the sum of purchased fossil fuel, electric and steam energy, including that used in SYSTEMS and LOADS.

Columns 14 — TOTAL SOURCE ENERGY
The information in this column is the energy used at the source. For each RESOURCE, the energy consumption at the site is divided by the corresponding SOURCE-SITE-EFF to arrive at the energy consumed by the generating station and the results are summed.

REPORT PS-B — MONTHLY PEAKS AND TOTAL ENERGY USE

The information reported treats the fuels and utilities used by the building. The report shows these energy sources for each month, plus the peak energy demand and the day and hour it occurred. Note that the values are at the site. To calculate the peak electrical demand, the user should divide PEAK in MBTU by 3413 Btu/kW.

REPORT PS-C — EQUIPMENT PART LOAD OPERATION

This report shows the hours spent in each part load ratio range, in increments of 10%. If equipment is oversized, the equipment will never indicate any hours in the 100-110% range.

The TOTAL HOURS entry differs from the total hours in other reports. In this report, TOTAL HOURS refers to the total hours of the day during which one or more units of a given equipment type are operating. This sum is independent of the number of units operating. If three boilers are operating during a given hour, TOTAL HOURS is increased by one rather than three.

ANNUAL LOAD is the useful load handled by the equipment. A FALSE LOAD occurs when, due to the OPEN-CENT-UNL-RATIO value (the minimum point on the part load curve), the compression chillers output more than the plant requests. The excess load over demand is the FALSE LOAD.

ELEC USED is the total electrical energy used by the indicated equipment type. THERMAL USED refers either to the fuel consumed or the heat required for operation, from wherever it arises.

If there had been more than one piece of equipment of the same type, staged for availability, the first line for each type is the hours spent in the partial load ratio range for the operating capacity, i.e., the capacity of the equipment actually running that hour. The second line is hours spent for each type in the partial load ratio range for the total capacity, i.e., the capacity of all the equipment available, whether running or not. (This total is taken from the values of MAX-NUMBER-AVAIL, not of INSTALLED-NUMBER). Obviously, when only one piece of equipment is installed, the operating capacity and the total capacity are identical.

REPORT PS-D — PLANT LOADS SATISFIED

The intent of this report is to flag those situations where the plant is not able to meet the loads imposed by both systems and other plant equipment. This is of special importance in those cases where equipment is intentionally undersized in order to improve part load performance or to reduce costs.

When a hot or cold storage tank is included among the plant equipment, a separate report is given at the bottom and describes the contribution to the heating and cooling demands made by the storage tanks.

The TOTAL LOAD ON PLANT for heating (cooling) is the sum of the demand from SYSTEMS, the consumption by PLANT, the loss from the storage tank and the heat (coolth) remaining in the storage tank at the end of the run. The last is still recoverable and is reported as RESIDUAL.

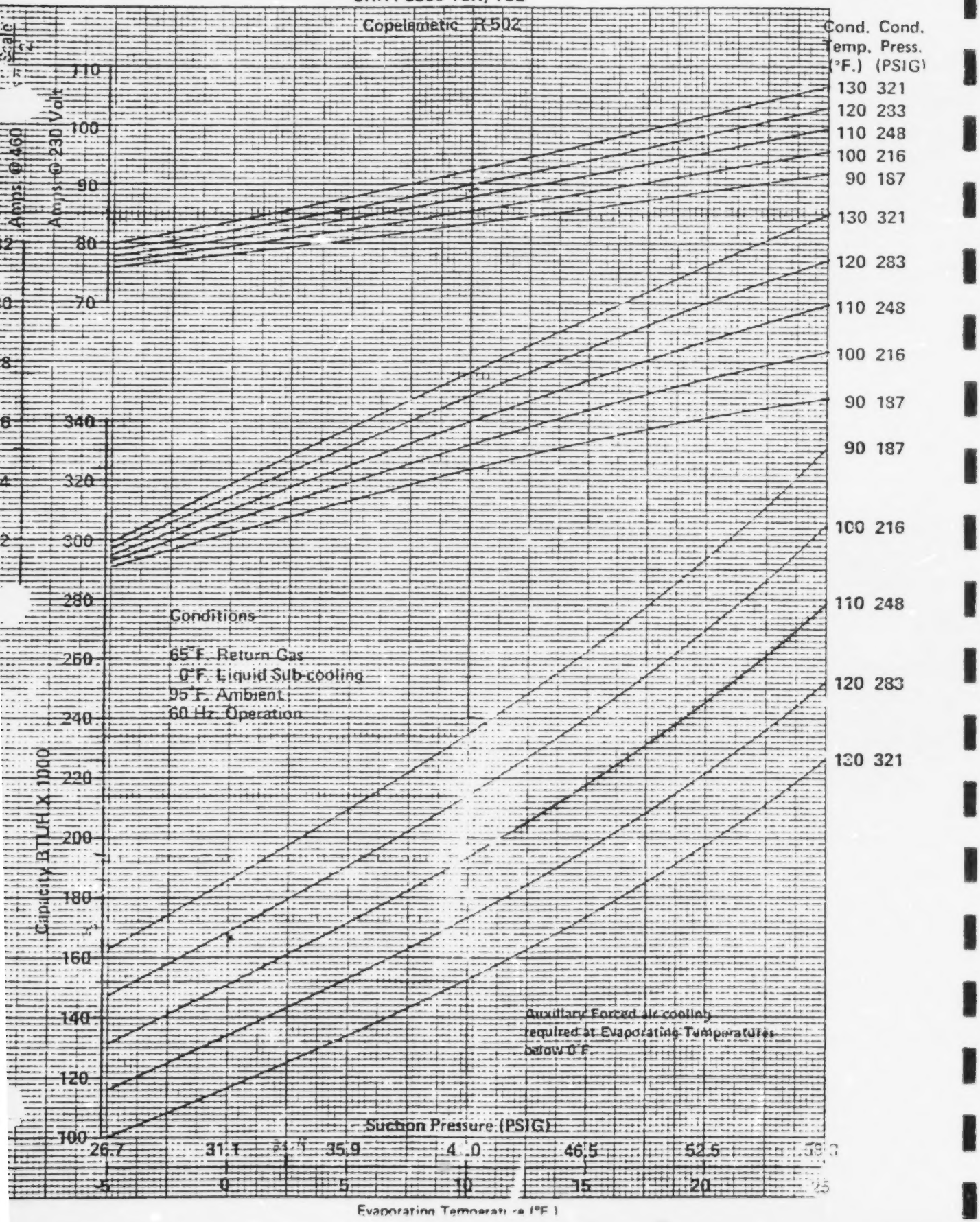
The user should be aware that, when PLANT begins its simulation, it assumes that there is no useable energy in the storage tanks. Furthermore, at the end of the simulation there may be significant amounts of RESIDUAL energy remaining. No account of this residual energy is made in other PLANT reports, with the consequence that the total fuel use reported overestimates the heating load met for the run period. The residual energy in the tank is available for the next period of time (beyond the run period) and should properly be subtracted from the reports on site energy used.

NOTE: A cooling tower can always reject any heat load given to it. If the tower is undesigned, the leaving tower water temperature will be hotter which will degrade the chiller performance.

APPENDIX B

ICE-MAKING PLANT PERFORMANCE CHARACTERISTICS

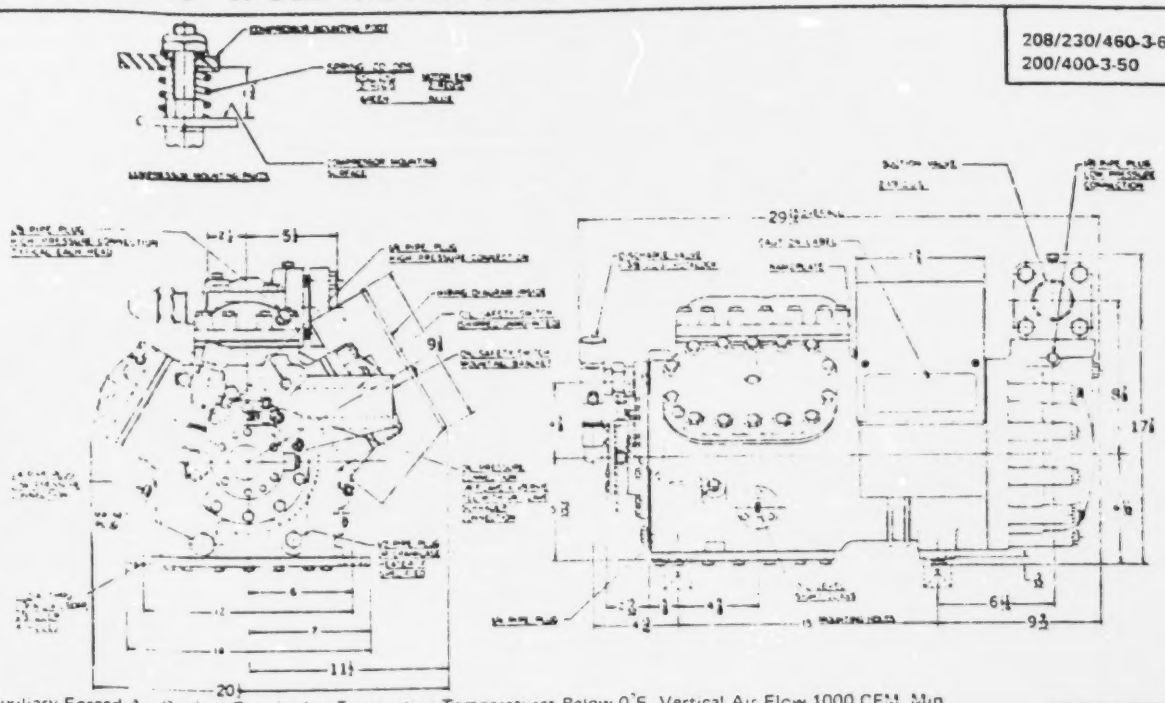
6RH1-3500-TSK, TSE



COPELAMETIC® R-502 MOTOR-COMPRESSOR

6RH1-3500-TSK

208/230/460-3-60
200/400-3-50



Auxiliary Forced Air Cooling Required at Evaporating Temperatures Below 0°F. Vertical Air Flow 1000 CFM. Min.
Copeland Fan Assemblies Available: 550-0211-00 (208/230 V.) and 550-0211-01 (460 V.)

497-0051-00

APPLICATION

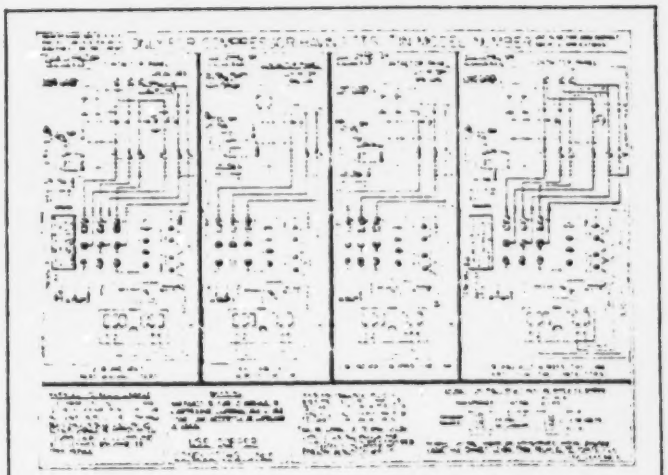
Evap. Temp. Range (°F.)	25° to -5°
Refrigerant	R-502
Compressor Cooling	Refrigerant
Internal Relief Valve Setting	.375 PSIG Differential

RATED PERFORMANCE

Capacity (BTU/Hour)	151,000
Motor Input (Watts)	23,000
Amps.	81.0
Specific Cap. (BTU/Watt)	6.56
Rating Conditions:	
Evap. Temp.	0°F.
Cond. Temp.	110°F.
Ambient Temp.	95°F.
Liquid Temp.	110°F.
Return Gas	65°F.

COMPRESSOR DATA

Bore X Stroke (In.)	2-11/16 X 2-3/16 6 Cyl.
Displacement (Cubic Feet/Hr.)	4530.0
Displacement (Cubic In. Rev.)	74.50
Speed (RPM)	1750
Suction Conn. I.D. (In.)	2-1/8 Sweat
Discharge Conn. I.D. (In.)	1-3/8 Sweat Rotalock



052-0647-00

MOTOR DATA

Motor Type 3 Ø	Induction Run
Voltage Range (208/230 P.W.S.)	187-253
Nameplate Rating ½ Winding (Amps)	70.0
Locked Rotor Rating ½ Winding (Amps)	340.0
oltage Range (208/230 A.C. Line)	187-253
Nameplate Rating (Amps)	140.0
Locked Rotor Rating (Amps)	565.0
Voltage Range (460 A.C. Line)	414-506
Nameplate Rating (Amps)	70.0
Locked Rotor Rating (Amps)	283.0

MOTOR PROTECTION

Type (Pilot Duty)	Internal Thermal Sensors
Manufacturer	Robertshaw
Solid State Module	Pilot Circuit
Manufacturer	Robertshaw
Manufacturer No.	MP-23-1003
Copeland No.	071-0398-00 (208/230 V.)

OIL CHARGE

Viscosity	150
Grade	Suniso 3GS
Initial Charge (fl. oz.)	160
Recharge (fl. oz.)	144

WEIGHTS (APPROX.)

Net	484 lbs.
Shipping	507 lbs.

Copeland®

SPECIFICATION NUMBER
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